

Pygmy Nuthatch (*Sitta pygmaea*): A Technical Conservation Assessment



**Prepared for the USDA Forest Service,
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COVER PHOTO CREDIT

Pygmy nuthatch (*Sitta pygmaea*). © Dave Bruess, photographer. Used with permission.

LIST OF ERRATA

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF PYGMY NUTHATCH

Status

Although pygmy nuthatch (*Sitta pygmaea*) populations appear to be stable range-wide, currently available data do not provide reliable information on the status or trend of populations in USDA Forest Service Rocky Mountain Region (Region 2). The species' naturally patchy distribution, the inaccessibility of much of its habitat, and the road-based nature of the Breeding Bird Survey have collectively resulted in small sample sizes and a high degree of variability associated with pygmy nuthatch survey data in Region 2. Nevertheless, due to its association with unmanaged mature ponderosa pine (*Pinus ponderosa*) forests, a habitat type that has decreased substantially in recent years, the pygmy nuthatch is considered a management indicator species or species of local concern on numerous national forests within Region 2.

Primary Threats

Degradation of mature ponderosa pine forests through timber harvesting and fire suppression represents the primary threat to the health of pygmy nuthatch populations in Region 2. Both practices reduce pygmy nuthatch foraging, breeding, and roosting habitats directly by removing large live and dead trees, and indirectly by shifting forest structure from an open canopy comprised of few large trees to a closed canopy comprised of many small trees. Fire suppression and livestock grazing interact to form another important threat, an increased risk of stand-replacing wildfires that reduce habitat availability and quality. Because pygmy nuthatches roost communally, often in large numbers during the winter, roost cavity availability may be an important limiting factor.

Primary Conservation Elements and Management Considerations

Conservation and management considerations for pygmy nuthatches should focus on maintaining a landscape of open-canopy, mature and old-growth ponderosa pine forest, with clusters of large, standing dead trees (i.e., snags) and/or live trees with substantial dead sections scattered throughout. Broad-scale habitat management that minimizes the removal of standing trees, live and dead, and introduces fire back into the system, while reducing grazing pressure by livestock, will likely ensure the health of pygmy nuthatch populations.

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INTRODUCTION

This conservation assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS) (**Figure 1**). The pygmy nuthatch (*Sitta pygmaea*) is the focus of an assessment because it is classified as a Management Indicator Species (MIS) on several Region 2 forests, including Arapahoe-Roosevelt, Black Hills, Nebraska, Rio Grande, and White River. Within the National Forest System, MIS serve as barometers for species viability at the forest level. By monitoring a MIS, managers can 1) estimate the effects of planning alternatives on fish and wildlife populations (36 CFR 219.19 (a)(1)), and 2) monitor the effects of management activities on species via changes in population trends (36 CFR 219.19 (a)(6)).

This assessment addresses the biology of the pygmy nuthatch throughout its range in Region 2. The

nature of the assessment leads to some constraints on the specificity of information for particular locales. That is, given the limited information available from field studies and its origin from throughout the species' range, only limited inference can be made for specific situations within Region 2. This introduction outlines the goal and scope of the assessment and describes the process used in its production.

Goal

This species conservation assessment is designed to provide land managers, biologists, and the public with a thorough discussion of pygmy nuthatch biology, ecology, conservation, and management. Assessment goals limit the scope of the work to critical summaries of current scientific knowledge, discussions of the conservation implications of that knowledge, and outlines of information needs. The assessment does not seek to prescribe specific land management. Rather, it provides the ecological background upon which management



Figure 1. National forests and national grasslands within USDA Forest Service Region 2 (map courtesy of USDA Forest Service Region 2).

must be based and focuses on consequences of changes in the environment that result from management (i.e., management implications). This assessment also cites management recommendations proposed elsewhere and examines the success of recommendations that have been implemented. Potential and known effects of management on the pygmy nuthatch may therefore be recognized and used by managers to direct land management decisions.

Scope

The pygmy nuthatch conservation assessment examines the biology, ecology, conservation, and management of the species with specific reference to the geographic and ecological characteristics of USFS Region 2. Although much of the literature on the pygmy nuthatch originates from field studies conducted outside of this region, this document places that literature in the ecological and social contexts of the central and southern Rocky Mountains. Similarly, this assessment is concerned with characteristics of the pygmy nuthatch in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on the pygmy nuthatch were referenced in the assessment, nor were all published materials considered equally reliable. The assessment strongly emphasizes refereed literature. We considered non-refereed publications and reports with greater skepticism and cited them only when refereed information was not available. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of the species, but these data required special consideration because of the diversity of persons and methods used in their collection.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge in which competing ideas regarding how the world works are measured against observations. However, because our observations and descriptions of the world are always incomplete, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). It is often

difficult, however, to conduct critical experiments in the ecological sciences, and thus observations, inference, good thinking, and models often must be relied upon to guide the understanding of ecological relationships (Hilborn and Mangel 1997).

In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. For example, despite the rich literature on pygmy nuthatch ecology (e.g., habitat relationships), relatively little is known about many aspects of the species' demography. We dealt with this by considering the full range of data available and noting the limitations of the data and, hence, of our conclusions. Alternative approaches to developing knowledge (e.g., modeling, critical assessment of observations, inference) were accepted as sound approaches to understanding the pygmy nuthatch.

Publication of Assessment on the World Wide Web

To facilitate use of these species conservation assessments, they are being published on the USFS Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and managers, and the public, more rapidly than publishing them as reports. It also facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Conservation assessments developed for the Species Conservation Project have been peer-reviewed prior to release on the Web. Through a process administered by the Society for Conservation Biology, this report was reviewed by two recognized experts to provide critical input on the manuscript. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

The pygmy nuthatch is a MIS on the Arapahoe-Roosevelt, Rio Grande, and White River national forests in Colorado, the Black Hills National Forest in South Dakota, and the Nebraska National Forest in Nebraska. MIS designation on these Region 2 forests is due to the pygmy nuthatch's close association with unmanaged mature ponderosa pine forests, a habitat type that has

declined substantially in recent years (Hutto 1989, Wisdom et al. 2000), and because numerous lines of evidence suggest that negative changes in its population status within managed ponderosa pine forests may reflect adverse changes in the community as a whole (Diem and Zeveloff 1980). The pygmy nuthatch is also recognized as a “species of local concern” by the Bighorn National Forest in northern Wyoming.

The Natural Heritage Program’s global and national status rankings for the pygmy nuthatch are G5 and N5 (secure), respectively (NatureServe 2004). For states within USFS Region 2, Natural Heritage status rankings are S2S3 (imperiled-vulnerable) for South Dakota and Wyoming, S3 (vulnerable) for Nebraska, and S4 (apparently secure) for Colorado (NatureServe 2004). Keinath et al. (2003) consider the pygmy nuthatch to be S2 (imperiled) in Wyoming due to its limited range, low range occupation, and low abundance in the state, as well as uncertain abundance trends and moderate biological vulnerability. Similarly, the pygmy nuthatch’s rarity and limited distribution in South Dakota and Nebraska account for the relatively low status rankings in those states. In Wyoming, the pygmy nuthatch holds an additional classification as a Partners-in-Flight (PIF) Level 2 priority species in need of monitoring (Nicholoff 2003).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Within Region 2, Wyoming PIF considers the pygmy nuthatch a Level 2 priority species, in need of monitoring to determine its population trends in that state (Nicholoff 2003). They recommend that low elevation conifer forest, primarily ponderosa pine forest, be maintained as open stands of mature to old growth trees, retaining clusters of large trees and snags with cavities, with a minimum of seven to 12 large (>48 cm diameter at breast height [dbh]) standing snags per hectare. Recommendations include using prescribed fire to maintain open stands of forest, implementing a nest box program where snags are unavailable, minimizing the use of insecticides, and allowing insect outbreaks to proceed naturally (Nicholoff 2003).

A recently prepared conservation assessment of the pygmy nuthatch for the Black Hills National Forest (Ghalambor 2001) represents the only work that specifically addresses the species’ conservation and management in Region 2. Ghalambor (2001) noted that no specific management practices targeting the pygmy nuthatch have been implemented in any region,

but recognized that numerous standards and guidelines exist for the protection of snag-dependent species in general, which, if achieved, would benefit the pygmy nuthatch. However, despite the common management policy of retaining snags in harvested areas, it is unknown whether this practice is effective for pygmy nuthatches or if suggested policies of snag retention are being met by USFS (Ghalambor 2001). Suggestions for the minimum number of snags per hectare for cavity-nesters such as the pygmy nuthatch have ranged from as few as five to six per ha (Diem and Zeveloff 1980), to 6.4 to 6.7 per ha (Balda 1975, Scott 1979), to as many as 7.4 to 12.3 per ha (Clark et al. 1989). It has also been proposed that snags should be of relatively large diameter (48.3 cm dbh; Clark et al. 1989) and relatively soft to accommodate the weak excavating abilities of species like the pygmy nuthatch (DeGraaf et al. 1991). Various methods have been suggested for creating snags, including girdling trees, burning individual trees, injecting heart rot fungus into live trees, prescribed burning, and topping trees, as well as erecting nest boxes to create individual cavities. The Forest Plan for the city of Boulder, Colorado, for example, uses all of these methods to create snags for cavity-nesting birds.

Biology and Ecology

Description and systematics

The pygmy nuthatch (Order Passeriformes, Family Sittidae) is a small (length 9 to 11 cm, mass 9.3 to 11 g) songbird that inhabits pine forests of western North America. The sexes are alike, and immatures are similar to adults in appearance. The crown is gray-brown, outlined below by a dark eye-line and bordered by a pale spot on the nape. The face, breast, and belly are bright buff to white, blending into bluish-gray on the sides. The back, rump, and tail are bluish-gray, and the wings are mainly brownish-slate (Kingery and Ghalambor 2001).

The pygmy nuthatch and the brown-headed nuthatch (*Sitta pusilla*), a pine specialist of the southeastern United States, form a superspecies (Sibley and Monroe 1990) based on morphology, ecology, ethology, and genetics (Norris 1958, Kingery and Ghalambor 2001). The pygmy nuthatch consists of six subspecies that differ subtly in size, proportions, and plumage (reviewed by Kingery and Ghalambor 2001). *Sitta pygmaea melanotis* has the largest and most discontinuous range of all the subspecies, and it is the taxon that occurs throughout Region 2. The patchy distribution of this form (see Distribution and Abundance section below) corresponds to the likewise

patchy distribution pattern of ponderosa and other yellow pines used by pygmy nuthatches. *Sitta pygmaea melanotis* is distinguished from other subspecies by its dusky to almost black auriculars (“*melanotis*” comes from the Greek for “black-eared”). This subspecies generally exhibits a latitudinal gradient in size, with smaller northern birds giving way to larger southern birds (Norris 1958, Phillips 1986; reviewed by Kingery and Ghalambor 2001).

Distribution and abundance

Of the six subspecies of pygmy nuthatch, only *Sitta pygmaea melanotis* inhabits Region 2. Range-wide, this subspecies occurs from southern British Columbia southward through the Cascade and the Sierra Nevada ranges to Riverside County in southern California. Farther east, the form occurs as isolated populations southward through the Rocky Mountains (east to the Black Hills) and desert ranges of the Great Basin and southwestern United States, to northwestern Zacatecas, northern Jalisco, and northern Coahuila in Mexico (Kingery and Ghalambor 2001). On the central California coast, *S. p. pygmaea* occurs from Mendocino County south to San Luis Obispo County,

and *S. p. leuconucha* ranges from San Diego County, California south to northern Baja California, Mexico. Farther south, three additional subspecies occur within Mexico: *S. p. elii* in southwestern Nuevo Leon and southeastern Coahuila, *S. p. flavinucha* from Distrito Federal area to western Veracruz, and *S. p. brunnescens* from southwestern Jalisco to southwestern Michoacán (see Kingery and Ghalambor 2001).

Breeding Bird Survey (BBS) and Christmas Bird Count (CBC) data provide regional estimates of pygmy nuthatch abundance in areas containing census routes and count circles, respectively, and they reflect the species’ distribution (**Figure 2** and **Figure 3**). This depiction of geographic range and abundance is coarse, however, because data are extrapolated to estimate abundance between and around census routes and count circles, regardless of local habitat suitability (see Demography: Population size and density section below). In Region 2, Breeding Bird Atlas work provides a “ground-truthed” depiction of the pygmy nuthatch’s range in Colorado (**Figure 4**), and modeling the species’ habitat relationships portrays its distribution in Wyoming (**Figure 5**) and South Dakota (**Figure 6**).

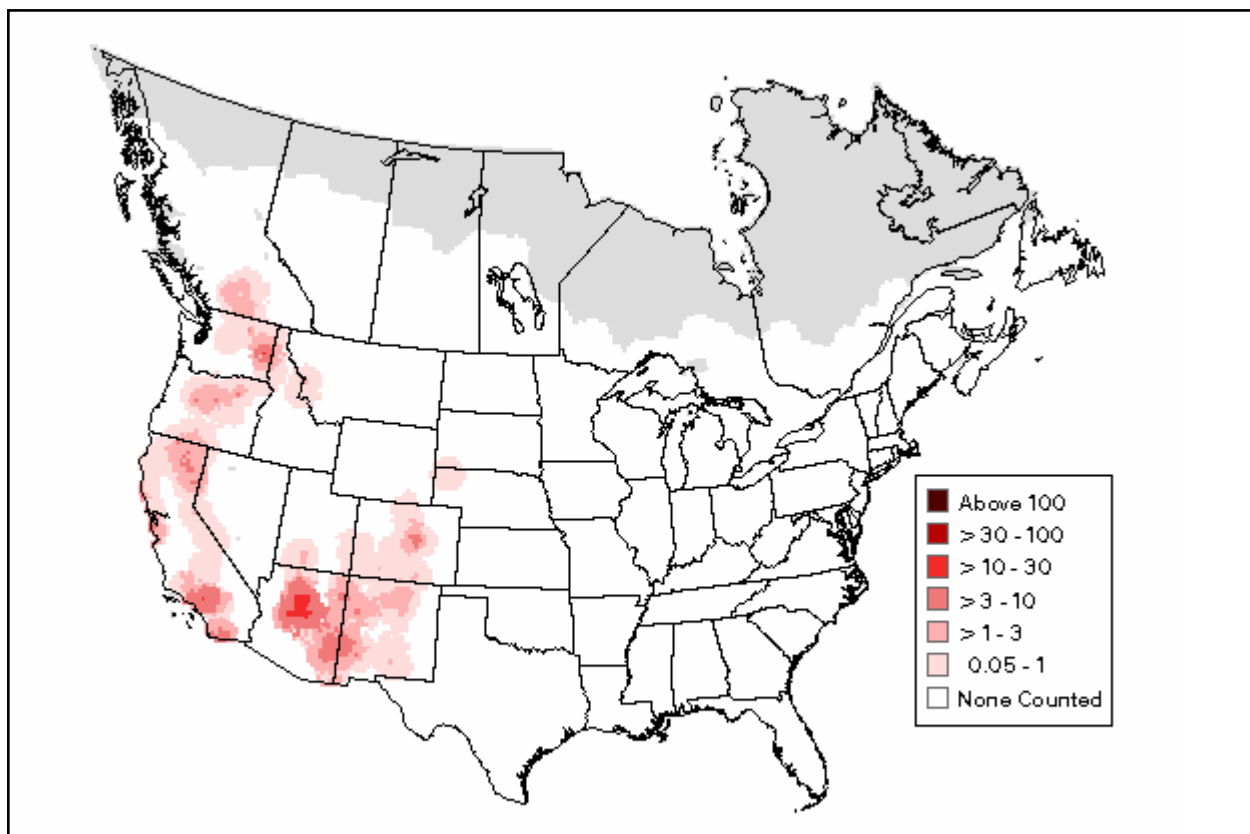


Figure 2. Summer distribution and relative abundance of the pygmy nuthatch from Breeding Bird Survey routes, 1994-2004 (Sauer et al. 2004).

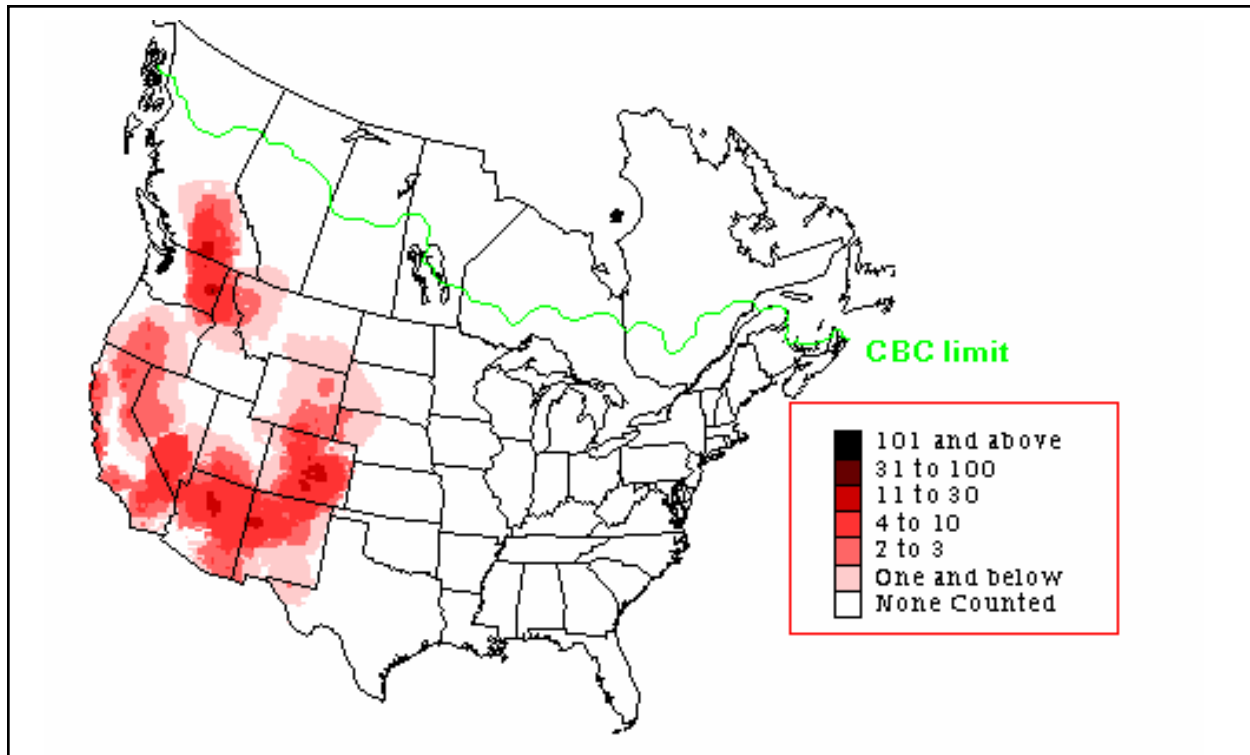


Figure 3. Winter distribution and relative abundance of the pygmy nuthatch from Christmas Bird Count circles, 1959-1988 (Sauer et al. 1996).

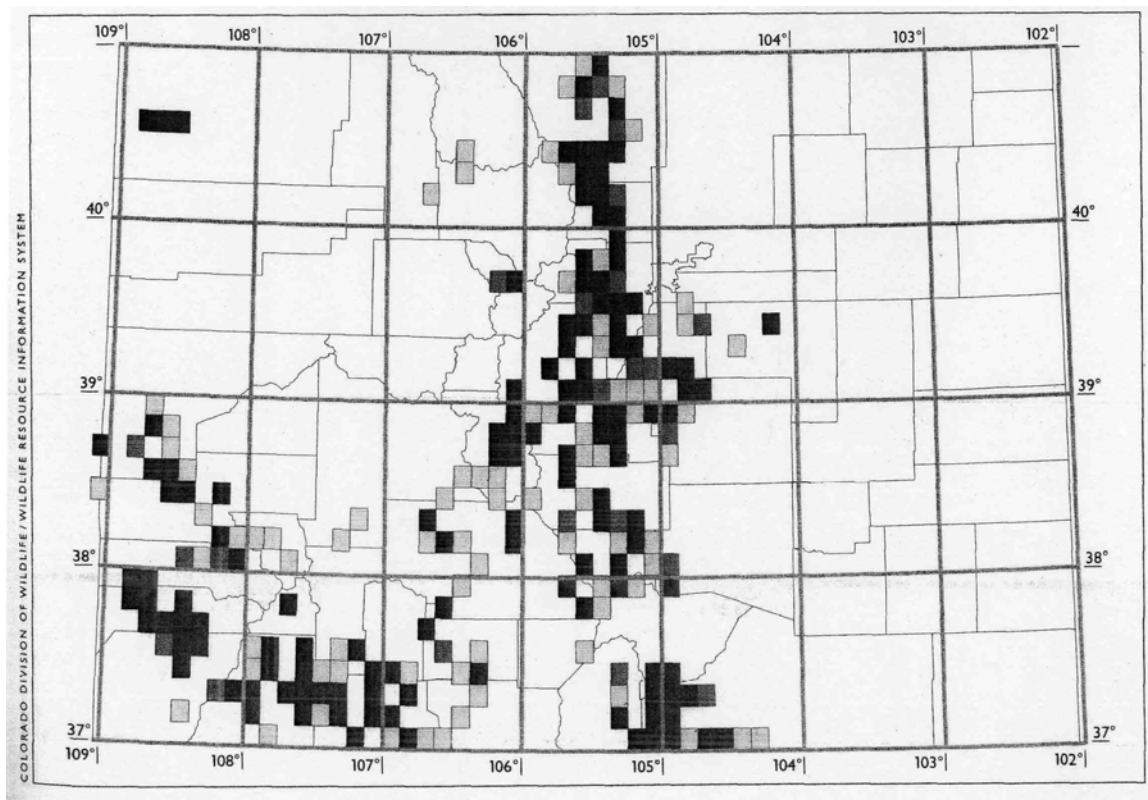


Figure 4. Breeding distribution of the pygmy nuthatch in Colorado from the Colorado Breeding Bird Atlas (Kingery 1998; map courtesy of the Colorado Bird Atlas Project).

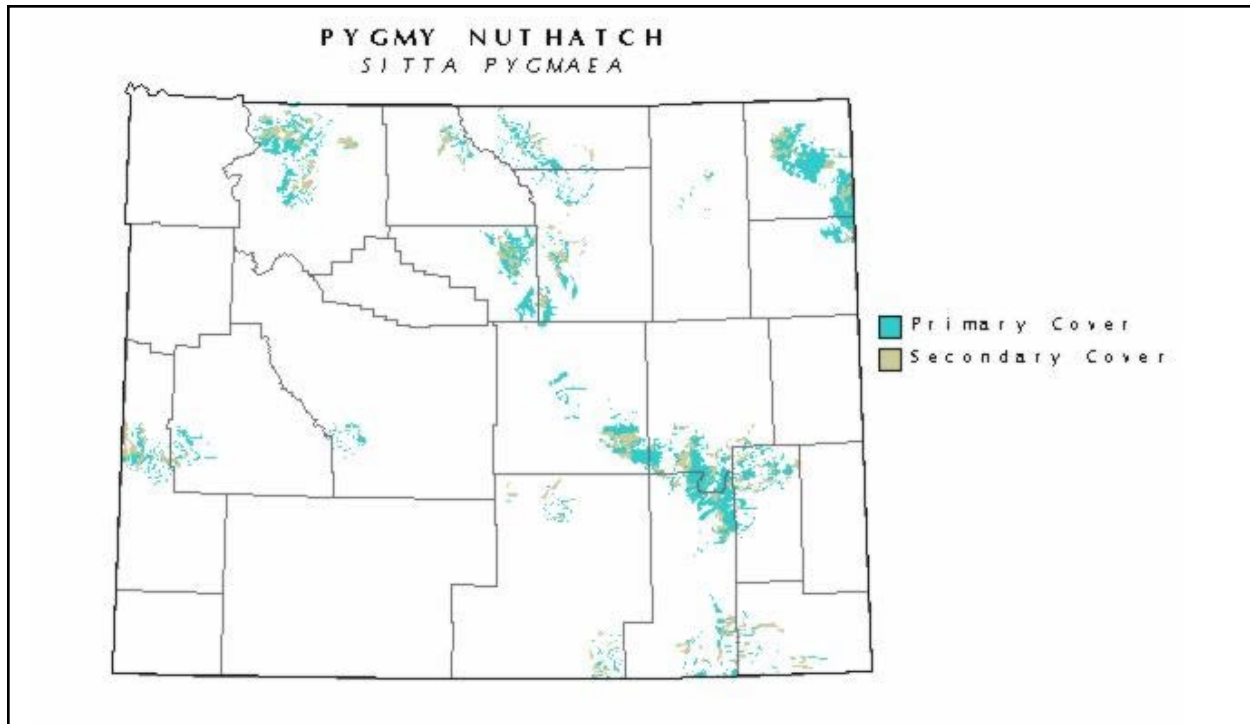


Figure 5. Distribution of pygmy nuthatch breeding habitat in Wyoming, as modeled by the Wyoming GAP project (online: <http://www.sdvc.uwyo.edu/wbn/gap.html>).

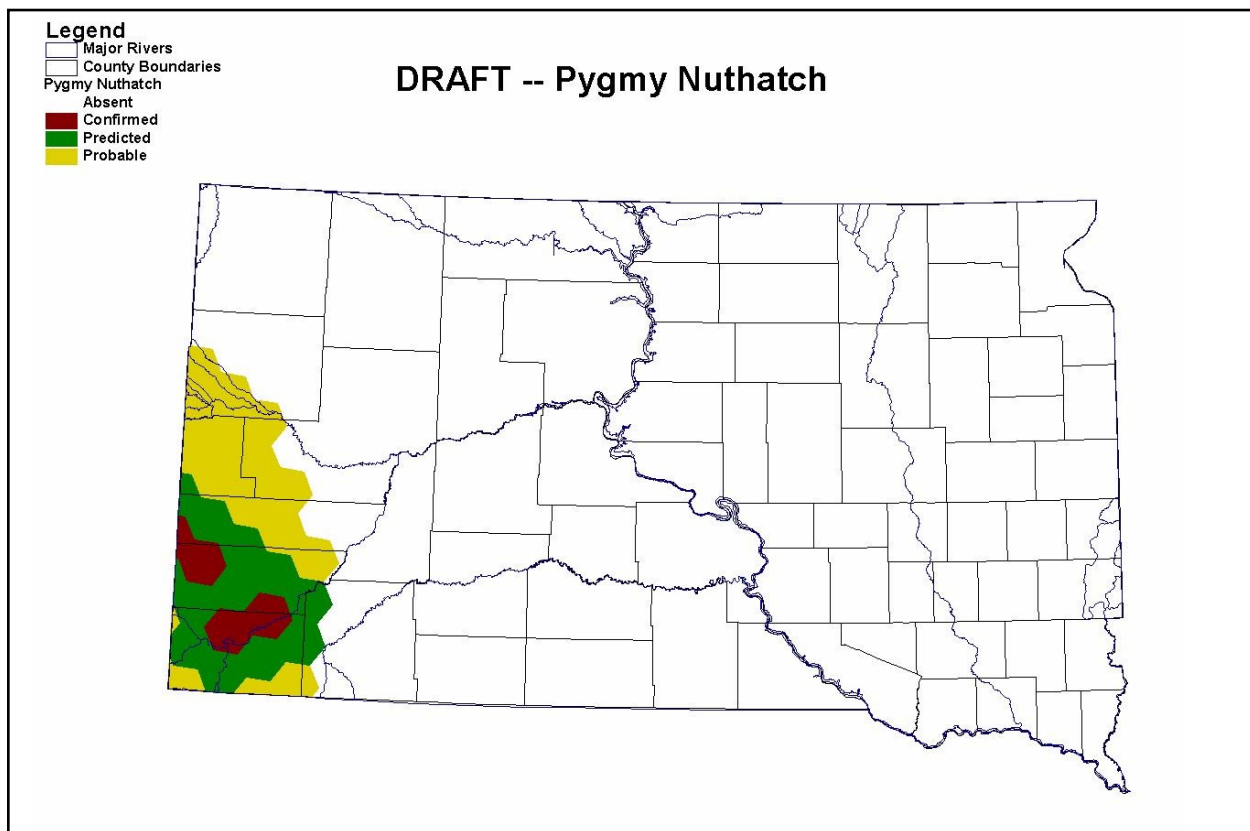


Figure 6. Distribution of pygmy nuthatch breeding habitat in South Dakota, as modeled by the South Dakota GAP project (online: <http://wfs.sdstate.edu/sdgap/sdgap.htm>).

Population trends

Regional population trends are not clear due to uncertainty in BBS data for the pygmy nuthatch in most states and regions. Survey-wide data, however, are based on adequate sample sizes and suggest that the pygmy nuthatch is stable overall (**Table 1**; Sauer et al. 2004). CBC data also suggest that pygmy nuthatch populations as a whole are stable, based on survey-wide analysis (**Table 2**). Long-term data for specific populations suggest that pygmy nuthatch populations may exhibit dramatic natural fluctuations. A central Arizona population, for instance, recently showed a dramatic crash. Constant-effort nest searching resulted in 23 to 65 (mean = 50.2) active nests per year in the period 1991-1996, but only two to five nests per year during the 1997-1999 period (Kingery and Ghalambor 2001). In a 21-year (1956-1995, intermittently) breeding bird census in Boulder County, Colorado, density averaged 20.1 pairs per 40 ha, but it

varied from none (three consecutive years) to 49 pairs per 40 ha (see Kingery and Ghalambor 2001). No definitive explanation currently exists for such dramatic population fluctuations, but it is likely that variation in annual survival due to variation in cone crops and/or climatic conditions may be important.

Seasonal movement patterns

Pygmy nuthatches are sedentary and resident throughout their range, exhibiting little broad-scale movement in most populations in most years. The sedentary nature of pygmy nuthatches may be related to their highly social behavior. Families form post-breeding flocks, and young males often remain on their natal territory to assist the parents in the following breeding season (see Breeding Biology section below). Post-breeding wandering to lower and higher elevations, and to non-pine habitats, does occur irregularly from July to December, sometimes on a large scale (Kingery and

Table 1. Breeding Bird Survey results (1966-2003) for the pygmy nuthatch in states, provinces, and regions with the species present on >10 routes (from Sauer et al. 2004). States within and regions including USFS Region 2 are in bold.

State/Province/Region	Trend	P	N	95% C. I.	R. A.
Arizona	-0.9	0.72	15	-5.5, 3.8	5.39
British Columbia [‡]	3.0	0.44	11	-4.3, 10.4	0.57
California	0.6	0.69	46	-2.2, 3.4	1.5
Colorado[‡]	-1.3	0.51	19	-5.0, 2.4	0.53
New Mexico [‡]	0.3	0.93	15	-6.1, 6.7	1.07
Oregon	2.1	0.17	18	-0.8, 5.0	1.02
Southern Rockies[†]	-2.9	0.00	17	-4.5, -1.4	0.68
Central Rockies [‡]	3.1	0.41	19	-4.1, 10.3	0.36
Survey-wide	0.3	0.70	139	-1.4, 2.0	1.05

Trend = estimated % change/year, N = number of routes/year, and R. A. = relative abundance (birds/route).

[‡]Data with a deficiency: low regional abundance (<1.0 birds/route), low sample size (<14 routes), or imprecise data (3%-per-year change not detectable).

[†]Data with an important deficiency: very low regional abundance (<0.1 birds/route), very low sample size (<5 routes), or very imprecise data (5%-per-year change not detectable).

Table 2. Christmas Bird Count data (1959-1988) for the pygmy nuthatch (from Sauer et al. 1996). States within and regions including USFS Region 2 are in bold.

Region	Trend	N	95% C. I.	R. A.
Arizona	0.1	18	-5.2, 5.5	7.12
California	1.5*	63	0.0, 3.0	2.49
Colorado	2.0	27	-0.2, 4.2	7.40
Oregon	3.2	15	-7.9, 14.2	1.75
Survey-wide	0.8	184	-0.5, 2.2	5.10

Trend = estimated % change/year, N = number of count circles/year, and R. A. = relative abundance (birds/100 party hours).

* = trend significant (P < 0.05)

Ghalambor 2001). Vagrants occasionally occur away from the mountains and have been seen at numerous sites in the Great Plains, along the Pacific coast, and in southwestern deserts (Kingery and Ghalambor 2001).

Subspecific identity of most vagrant individuals is not known, but it appears likely that the majority of vagrants are probably of the *melanotis* subspecies. This is likely a reflection of this subspecies' large, discontinuous range rather than an indication that it is more prone to movements than other subspecies. Evaluating the degree to which pygmy nuthatch populations are isolated from other populations, regardless of subspecies, is currently not possible due to a lack of information. Nevertheless, given the patchy distribution of populations and the apparent rarity of broad-scale dispersal, it appears unlikely that there is much opportunity for exchange of individuals between distant localities (e.g., Black Hills and Bighorn Mountains) (Ghalambor 2001).

Habitat

General

Throughout their geographic range, pygmy nuthatches are closely associated, almost exclusively, with long-needled pine (e.g., ponderosa and Jeffrey pine [*Pinus jeffreyi*]) forests, and they are often one of the most abundant bird species in ponderosa pine forest (Kingery and Ghalambor 2001). Within this yellow pine forest association, pygmy nuthatches also use associated elements such as oak (*Quercus*) species, Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), various other pine (*Pinus*) species, quaking aspen (*Populus tremuloides*), and maple (*Acer* spp.) in drainages and riparian areas, but typically only where there is a significant component of the preferred pine (e.g., ponderosa pine) (Kingery and Ghalambor 2001). In the Sierra Nevada range of California, pygmy nuthatches typically occur in park-like forests of ponderosa and Jeffrey pines, but occasionally they range higher in elevation into open stands of large lodgepole pines (*Pinus contorta*) (Gaines 1988, Shuford and Metropulos 1996). Pacific coast and Mexican populations use a suite of other pine species (see Kingery and Ghalambor 2001) that comprise forests generally similar to ponderosa pine forest in structure.

In the ponderosa pine forest type, density of pygmy nuthatches is strongly correlated with the abundance of ponderosa pine trees, more so than any other bird species (Balda 1969). The pygmy nuthatch prefers old-growth or mature, undisturbed forests that

contain a number of large snags (Szaro and Balda 1982). Unlogged forests support significantly larger pygmy nuthatch populations than logged forests (Franzreb and Ohmart 1978, Brawn 1988, Sydesman et al. 1988), reflecting the importance of foliage volume and snag density as essential habitat components. Pygmy nuthatch abundance correlates significantly with ponderosa pine foliage volume (O'Brien 1990), and it is inversely correlated with trunk volume, suggesting that the species needs heterogeneous stands of well-spaced, old pines and vigorous trees of intermediate age (Balda et al. 1983). Logging practices that remove snags may result in pygmy nuthatch numbers declining by half (Scott 1979). The species' dependence on ponderosa pine forests with high amounts of foliage volume and numerous snags has caused the pygmy nuthatch to be regarded as one of the best indicator species for overall health of bird communities in mature ponderosa pine forests (Szaro and Balda 1982). (Note that we use the term "snag" in referring to dead trees as well as dead sections of live trees [e.g., dead sections caused by lightning scars]).

Within Region 2, the distribution of pygmy nuthatches coincides very closely with the distribution of ponderosa pines (Peterson 1995, Jones 1998, Sharpe et al. 2001, Nicholoff 2003). In Colorado, 66 percent of Breeding Bird Atlas observations of pygmy nuthatches were in ponderosa pine forest (**Figure 7**) or habitats (e.g., pinyon-juniper, mixed conifer, mixed conifer-aspen, montane riparian) with a ponderosa pine component (Jones 1998). Local colonization of lodgepole pine forest may occur occasionally (Jones 1998).

Foraging habitat

The pygmy nuthatch forages almost exclusively in pine trees. Individuals explore the entire tree by climbing up, down, over, and under bark surfaces to search for insects in or on needle clusters, cones, twigs, branches, and the trunk (Stallcup 1968, Bock 1969, McEllin 1978, 1979b, Ewell and Cruz 1998). Pygmy nuthatches spend most of their time in areas with the highest density and greatest cubic feet of foliage (Balda 1967), generally foraging higher in the tree and farther from the trunk than the white-breasted nuthatch (*Sitta carolinensis*) and mountain chickadee (*Poecile gambeli*), which are common flock associates (McEllin 1979b).

Four studies, all conducted in Region 2, quantify how pygmy nuthatches use different foraging zones of trees (Stallcup 1968, Bock 1969, McEllin 1978, 1979b, Ewell and Cruz 1998). Use of different foraging zones



Figure 7. Pygmy nuthatch breeding habitat: open ponderosa pine forest with pine snags, Rocky Mountain National Park, Larimer County, Colorado (photograph by R.C. Dobbs, July 2005).

remains relatively constant within the breeding and non-breeding seasons, but it differs between seasons. During the non-breeding season, pygmy nuthatches spend less time foraging on trunks and large branches, and more time on small branches, needles, twigs, and cone clusters, than during the breeding season (summarized in Kingery and Ghalambor 2001). This non-breeding season shift to cone clusters presumably reflects a greater reliance on pine seeds during the non-breeding season. Pygmy nuthatches also spend more time in each foraging zone and use a greater proportion of a tree's vertical height during the non-breeding season than in the breeding season (McEllin 1978, 1979b). The time that pygmy nuthatches spend in different foraging zones does not vary with foraging height, tree diameter, or location within the tree (McEllin 1978). During the non-breeding season in Boulder County, Colorado, pygmy nuthatches spend 92 percent of their foraging time in ponderosa pine, 5.3 percent in Douglas-fir, 1.4 percent in dead woody material, and 1.1 percent on the ground. When in pines, the birds spend 34.6 percent of their time on the trunk, 25.4 percent on branches, and 22.0 percent on needles and twigs (Bock 1969). Stallcup (1968) also observed pygmy nuthatches foraging on

fallen pinecones on the ground during the breeding and non-breeding seasons.

Nesting habitat

Because it excavates nest cavities primarily in dead pine trees and live trees with dead sections, the pygmy nuthatch prefers mature, undisturbed forest that contains an adequate number of large snags (Szaro and Balda 1982). By comparing pygmy nuthatch densities before and after logging on two plots that differed only in snag removal procedures, Scott (1979) showed that populations decreased by half (16.3 pairs to 7.6 pairs per 40 ha) on the plot where snags were removed, and that populations increased slightly on the plot where snags were left standing (18.7 to 22.6 pairs per 40 ha).

Nest tree characteristics: Pygmy nuthatches primarily use ponderosa pine and other long-needled yellow pines for nesting, but they will occasionally use other conifers and quaking aspen. Variation in tree species used appears to vary somewhat with habitat type. The subspecies that occurs in Region 2, *Sitta pygmaea melanotis*, nests almost exclusively in areas

dominated by conifers (McEllin 1979a, Brawn and Balda 1988a). Of 153 nests in British Columbia, 74 percent were in ponderosa pine trees while 6 percent were in aspen, 5 percent in Douglas-fir, and 7 percent in fence posts (Campbell et al. 1997). In New Mexico, seven of eight nests were in ponderosa pine; the other was in a cottonwood (*Populus* sp.) snag (Travis 1992). In Montana, eight of nine nests were in ponderosa pine while one was in aspen (Storer 1977). Of 33 nests in California, all were in unspecified pine species (Grinnell and Linsdale 1936). At a mixed conifer-aspen forest site in central Arizona, however, where large aspen snags were numerous, 64 percent of 287 pygmy nuthatch nests were in aspen, 23 percent were in fir, and only 5 percent were in pine (Kingery and Ghalambor 2001). The species also nests in Gambel oak (*Quercus gambelli*) occasionally in Arizona (W.J. Sydeman personal communication 2005). There are few data available on nest tree species use by other subspecies, but in Marin County, California, *S. p. pygmaea* nests almost exclusively in Bishop pine (*Pinus muricata*) and occasionally in broad-leaved oaks (Shuford 1993).

The pygmy nuthatch excavates nest cavities and uses existing cavities in dead trees or dead sections (e.g., resulting from lightning) of mature live trees (Figure 8). In Arizona, 73 percent of nests were new excavations, 23 percent were in cavities excavated in previous years, and 4 percent were in natural cavities ($n = 237$ nests; T.E. Martin cited in Kingery and Ghalambor 2001). Nest cavities are typically located in the trunks of trees, less commonly in the branches (Hay and Güntert 1983). In Montana, five of nine active nests were in dead pines; the other four were in live pines (Storer 1977). Of 294 nests in central Arizona, 51.7 percent of pygmy nuthatch nests were in dead trees, and 48.3 percent were in live trees, including dead sections of live trees (Kingery and Ghalambor 2001). Nest cavities are often placed under or near existing broken-off branches (Kingery and Ghalambor 2001). McEllin (1979a) reported that 23 of 26 nest cavities in Larimer County, Colorado had limbs below the entrance while the other three had limbs beside the entrance. Pygmy nuthatches also use nest boxes and increase their propensity to do so as the habitat becomes more open, with fewer live and dead trees (e.g., after clear-cutting) (Brawn 1988). Of 213 nests in British Columbia, 73 percent were in cavities, and 24 percent were in nest boxes (Campbell et al. 1997).

For pygmy nuthatch populations in Colorado, Montana, and Arizona, the mean height of nest trees is 16.03 m (± 2.89 SE), and the mean height of nest cavities is 10.57 m (± 2.83 SE) (Table 3). The mean diameter at

breast height of nest trees for pygmy nuthatches nesting in Arizona is 47.83 cm (± 10.35 SE) (Table 3).

Habitat surrounding nest tree: Li and Martin (1991) examined local habitat characteristics of pygmy nuthatch nest trees by comparing 11.3-m radius circular plots centered on nest trees with those centered on random trees of similar size and the same species. Results showed that plots surrounding pygmy nuthatch nest trees had significantly more aspen and conifer snags, more large conifers (>15 cm dbh), and fewer large deciduous trees (>15 cm dbh) in comparison with the randomly selected plots.

Territory size: Pygmy nuthatch pairs or family groups nest and live within year-round foraging territories, but they actively defend only the area around the nest tree during the breeding season (Norris 1958, McEllin 1978, 1979a). Pygmy nuthatches attempt to exclude non-members of the resident flock from the entire foraging territory during the non-breeding season (Norris 1958), except just prior to roosting when multiple family groups may roost together (Güntert et al. 1989; see Roosting habitat section below). Territory size ranges from 0.54 to 8.15 ha (Norris 1958, Balda 1967, Storer 1977), varying with number of nuthatches present (e.g., pair or family group) and density of pine trees and available nest sites (e.g., snags or nest boxes). Territory size is significantly larger on heavily logged plots than on thinned plots (Brawn and Balda 1988a) and on plots with nest boxes in snag-poor habitats (Brawn and Balda 1988a, Bock and Fleck 1995).

Roosting habitat

Pygmy nuthatches use cavities as roost sites year-round. During the breeding season, pairs, and helpers if present, roost in the nest cavity together (Norris 1958, Kingery and Ghalambor 2001). During the non-breeding season, family groups or larger flocks share a roost cavity each night, a behavior that significantly reduces heat loss. Weather and cavity characteristics (e.g., type of wood, thickness of bole, size of entrance, and depth of cavity) that provide protection from outside ambient temperature both affect cavity selection and roosting behavior during the non-breeding season (Hay and Güntert 1983). Pygmy nuthatches roost in larger flocks when snow covers the ground than when snow is absent, and begin roosting earlier in the evening as temperature decreases (Sydeman and Güntert 1983).

Pygmy nuthatches show clear seasonal cavity preferences that are related to thermal insulation and ventilation (Table 4). The birds choose roost sites that



Figure 8. Typical pygmy nuthatch nest cavity, located beneath branch in ponderosa pine snag, Rocky Mountain National Park, Larimer County, Colorado (photograph by R.C. Dobbs, July 2005).

Table 3. Characteristics of nest trees used by the pygmy nuthatch. States within USFS Region 2 are in bold.

Characteristic	Mean (SE/SD)	Range	Location	Source
<u>Nest tree diameter (cm)</u>				
	42.6 (0.78 SE)	13-100	Arizona	Li and Martin 1991
	58.4 (N/A)	27.9-93.9	Arizona	Scott et al. 1980
	67.8 (14.0 SD)	42-96	Arizona	Cunningham et al. 1980
<u>Nest tree height (m)</u>				
	16.2 (1.01 SE)	5.1-25.5	Colorado	McEllin 1979a
	9.4 (N/A)	1.7-25.0	Montana	Storer 1977
	9.8 (5.8 SD)	N/A	Arizona	Hay and Güntert 1983
	19.8 (N/A)	9.6-32.6	Arizona	Scott et al. 1980
	23.8 (N/A)	N/A	Arizona	Cunningham et al. 1980
<u>Nest cavity height (m)</u>				
	10.8 (0.73 SE)	3.5-17.2	Colorado	McEllin 1979a
	3.3 (N/A)	0.9-6.5	Montana	Storer 1977
	5.6 (2.2 SD)	N/A	Arizona	Hay and Güntert 1983
	13.7 (N/A)	2.6-25.6	Arizona	Scott et al. 1980
	18.9 (N/A)	N/A	Arizona	Cunningham et al. 1980
	15.9 (4.8 SE)	N/A	Arizona	Li and Martin (1991)

Table 4. Characteristics of pygmy nuthatch nest and roost cavities at an Arizona site (from Hay and Güntert 1983).

Type of cavity	Tree height (m)	Tree dbh (cm)	Tree diameter at cavity (cm)	Cavity height (m)	Cavity entrance area (cm ²)
Nest (10)	9.8 ± 5.8	39.2 ± 20.0	25.2 ± 18.3	5.6 ± 2.1	13.0 ± 0.9
Summer roost (11)	18.9 ± 9.9	64.5 ± 19.5	22.0 ± 11.5	7.9 ± 2.5	22.2 ± 15.1
Fall/spring roost (9)	24.5 ± 6.1	63.3 ± 17.3	34.9 ± 26.1	10.8 ± 3.5	21.7 ± 14.0
Winter roost (8)	23.2 ± 9.1	73.1 ± 20.3	56.6 ± 22.6	9.3 ± 2.6	11.2 ± 6.0

are higher in the tree than nest sites year-round, and higher during spring and fall than during summer (Hay and Güntert 1983). They use roost cavities with smaller entrance holes during fall, winter, and spring than during summer. Non-breeding roost sites (fall/spring, winter) tend to be in the trunks of trees while summer roost sites tend to be in or near branches (Hay and Güntert 1983). In winter, pygmy nuthatches use cavities in trees with larger trunk diameters, larger volumes that hold more birds, and smaller entrance holes than in summer, when the birds use cavities with large entrance holes, often with other cracks and openings (Güntert et al. 1989). Smaller groups of pygmy nuthatches use smaller cavities than larger groups, regardless of weather or season (Hay 1983).

Availability of roost cavities may limit winter populations of pygmy nuthatches. In northern Arizona ponderosa pine forest during the severe El Niño winter of 1983, large groups of 20 to 30 pygmy nuthatches, comprised of family groups from neighboring feeding territories, regularly searched for and roosted together

in cavities (Sydeman and Güntert 1983). The birds spent up to two hours searching for roost cavities, during which time groups splintered and reformed as birds investigated multiple cavities before finally settling in a cavity for the night (W.J. Sydeman personal communication 2005). At one roost cavity, between 27 and 167 pygmy nuthatches (many of which were color-banded) from at least 12 different family groups roosted together regularly, with groups traveling 0.66 to 1.68 km to reach the roost site (Sydeman and Güntert 1983). These observations suggest that the availability of multiple potential roost cavities is an important component of pygmy nuthatch habitat during winter, and that individual roost sites may be important to the survival of local populations during severe winter conditions.

Food habits

During the breeding season, the pygmy nuthatch diet consists of 60 to 85 percent insects (Norris 1958, Anderson 1976), including beetles (Coleoptera), wasps

and ants (Hymenoptera), true bugs (Hemiptera), and caterpillars (Lepidoptera larvae) (Beal 1907, Norris 1958). The winter diet of *Sitta pygmaea melanotis* was similar to that of the breeding season in eastern Oregon (Anderson 1976) and in Napa County, California (Norris 1958). Farther south, in Monterey County, California, *S. p. pygmaea* shifts its diet to over 80 percent vegetable matter, primarily pine seeds, during the winter (Norris 1958). The relative importance of insect and plant components of the pygmy nuthatch's diet in Region 2 is not known, but it is likely that pine seeds are an important source of food at times, especially winter.

Pygmy nuthatches use their bills to probe and pry into cracks and crevices, glean from foliage and bark surfaces, flake off bark, and peck into pine seeds wedged into bark or on the upper surface of branches (McEllin 1979b, Kingery and Ghalambor 2001). Pygmy nuthatches in Boulder County, Colorado, spend equal time probing, pecking/flaking, and gleaning during the breeding season, but they shift to spending more time probing and less time pecking/flaking or gleaning during the non-breeding season (Ewell and Cruz 1998). Pygmy nuthatches search for prey by hitching vertically up and down trunks and along branches, and by inspecting pine/needle clusters (Ewell and Cruz 1998; see Foraging habitat section above). Birds cache food year-round, for short- and long-term storage, by hammering items into crevices on upper sides of branches or under bark of trunks or branches (Norris 1958, Stallcup 1968). Foraging behavior of pygmy nuthatches, then, consists of searching for and capturing new food items, manipulating food items for consumption and caching, and caching and seeking previously cached food items (Kingery and Ghalambor 2001).

Breeding biology

The pygmy nuthatch is unique in being one of the few cooperatively breeding passerines in North America (Kingery and Ghalambor 2001). Typically, one third of all breeding pairs have one to three male helpers, which are usually one-year old progeny or other relatives (Storer 1977, Sydeman et al. 1988, Sydeman 1989, 1991). Helpers feed incubating females, nestlings, and fledglings, and they participate in defending the nest site. Most information on breeding biology comes from pygmy nuthatch populations in Arizona (e.g., Hay 1983, Sydeman et al. 1988) and California (Norris 1958). Nevertheless, basic aspects of breeding biology and behavior likely do not differ greatly among populations of *Sitta pygmaea melanotis*.

Phenology

Pair bonds appear to be long-term and maintained year-round (Norris 1958), but initial timing of pair formation remains unknown. Courtship and excavation of nesting cavities may begin as early as mid-March and extend through June range-wide, including Colorado (Kingery and Ghalambor 2001). Excavation occurs over a three to six week period, depending on weather, hardness of wood, and changes in nest site preferences (Norris 1958). Following excavation, pygmy nuthatches build a cup nest inside of their cavity, using bark shreds, fine moss, grass, plant down, and other soft materials, including feathers (Kingery and Ghalambor 2001). Nest building records for *Sitta pygmaea melanotis* range from early April to mid- or late-May, occasionally into June (Kingery and Ghalambor 2001). Courtship feeding of the female by the male occurs frequently before and after copulation during nest-building and egg-laying, and throughout incubation (Norris 1958, Kingery and Ghalambor 2001).

Range-wide, records of *Sitta pygmaea melanotis* nests with eggs span from 21 April to 14 July, and nests with young from 29 April to 1 September (from Kingery and Ghalambor 2001). In Region 2, breeding phenology is well documented for Colorado, where Breeding Bird Atlas records show nest-building between 7 May and 12 June (n = 4), occupied nests from 24 May to 1 July (n = 14), nests with young from 3 June to 22 July (n = 19), and fledged young between 23 May and 25 August (n = 42) (Jones 1998). *Sitta pygmaea pygmaea* breeds earlier than *S. p. melanotis*.

Breeding behavior

Male and female pygmy nuthatches share equally the work of excavating and adding nest material to the nest cavity. Females lay a single egg per day, usually in the morning, and begin incubating after the clutch is complete. Incubation lasts 13.5 to 16 days (usually 14.5 to 15 days) in Montana (Storer 1977), and 12 to 17 days in British Columbia (Cannings et al. 1987). Only the female incubates, but the male, and helper(s) if present, roost overnight in the nest cavity with the female. The male, and helper(s) if present, regularly feed the incubating female, both while she is on and away from the nest. Eggs typically hatch within a 24-hour period; hatchlings have natal down and can raise heads to accept food after one day. Only the female broods the young, but both parents, and helper(s) if present, feed nestlings and fledglings. Young birds leave the nest when they are

14 to 22 days old, but they remain partly dependent on adults for 23 to 28 days post-fledging and may be fed by adults until 52 days post-fledging (Norris 1958).

Local post-breeding populations increase to levels well above breeding density and remain high until spring, when populations decline as family groups break up and birds disperse (McEllin 1978). While family groups often remain on territories year-round, post-breeding movements occur and are irregular with respect to habitat and geography, with birds wandering to both lower and higher elevations (Kingery and Ghalambor 2001). Irregular patterns of post-breeding wandering may be a result of local failures of ponderosa pine cone crops, but no definitive information is available.

Demography

Population size and density

The range-wide population estimate for the pygmy nuthatch is 2,300,000 individuals (Rich et al.

2004). Regionally, BBS data show highest numbers of pygmy nuthatches on routes in Arizona and southern California, while CBC data indicate highest numbers in central Arizona, west-central New Mexico, the Colorado Front Range, western Washington, and south-central British Columbia (**Figure 2**). Locally, pygmy nuthatch populations occur in variable breeding densities depending on habitat type, habitat quality, local conditions, and available nest sites. In Region 2, pygmy nuthatch density estimates range from nine to 23.1 pairs per 40 ha (**Table 5**). In Arizona ponderosa pine forests, density estimates (number of breeding pairs/40 ha) of *Sitta pygmaea melanotis* include 1.5 to 18.0 (Szaro and Balda 1979), 0.0 to 53.0 (Overturf 1979), 7.6 to 22.3 (Scott 1979), 1.0 to 42.0 (Cunningham et al. 1980), 0.0 to 50.0 (Brawn and Balda 1988b), 14.2 to 26.2 (Horton and Mannan 1988), and 7.7 to 16.0 (Siegal 1989). Timber harvesting strongly affects breeding density of pygmy nuthatches in Arizona (**Table 6**).

Population numbers tend to increase following the breeding season, remain high through the winter, and then decline when the breeding season begins

Table 5. Pygmy nuthatch breeding densities in USFS Region 2.

Location (county, state)	Habitat	Density (pairs/40 ha)	
		Range	Average
Boulder, CO	ponderosa pine	0-49	23.1
El Paso, CO	ponderosa pine w/ oak and mountain mahogany	1-43	9.1
Larimer, CO	aspen w/ scattered ponderosa pine	9-10	9.5
Jefferson, CO	ponderosa pine	9-19	14.0
Jefferson, CO	lodgepole pine	0-30	9.0

Table 6. Pygmy nuthatch breeding densities under different logging regimes in Arizona ponderosa pine forests.

Source	Logging regime	Density (pairs/40 ha)	
		Range	Average
Brawn and Balda 1988b	unlogged	26-50	37
Brawn and Balda 1988b	unlogged since 1920's	14-24	18.8
Brawn and Balda 1988b	moderately thinned	15-22	16.8
Brawn and Balda 1988b	severely thinned	2-9	3.3
Brawn and Balda 1988b	severely thinned (of pine only)	0-5	3.5
Brawn and Balda 1988b	clearcut	0	0
Scott 1979	unlogged (plot A)		16.3
Scott 1979	pinos logged / all snags removed (plot A)		7.6
Scott 1979	unlogged (plot B)		18.7
Scott 1979	1/3 of snags cut (plot B)		22.3
Scott 1979	unlogged (plot C)		13.6
Scott 1979	unlogged (plot C)		20.4

the following spring (McEllin 1979a). For example, a breeding density of 10.3 birds per 40 ha doubled to 29.8 birds per 40 ha during October-December, and then dropped to 19.6 birds per 40 ha during April-May (Stallcup 1968; see Population trends section above).

Age of first reproduction

Females breed during their second year (i.e., when they are one year old) and continue to breed annually (Norris 1958, Kingery and Ghalambor 2001). In contrast, males often spend their second year helping their parents instead of breeding themselves. At the population level, 17 to 40 percent of all nests have one to three helpers (Norris 1958, Kingery and Ghalambor 2001).

Reproductive success

Clutch size averages seven eggs, typically ranging from five to nine eggs. Average clutch size of *Sitta pygmaea melanotis* is 7.1 eggs in British Columbia (range 5-10, n = 41 clutches; Cannings et al. 1987), 7.2 in Oregon, California, and Arizona combined (n = 26; Norris 1958), 7.3 in Montana (n = 8; Storer 1977), and 6.9 in central Arizona (range 5-8, n = 12; T.E. Martin cited in Kingery and Ghalambor 2001).

Pygmy nuthatches produce a single brood per year, and they rarely attempt a second brood or a replacement following nest failure (Norris 1958, Sydeman et al. 1988, Kingery and Ghalambor 2001). Second broods are very rare (but see Sydeman et al. 1988), in part due to the long period between egg-laying and full independence of young birds (72-78 days; Norris 1958). Pygmy nuthatches have high reproductive success; 86.8 percent of nests successfully produce at least one offspring (Martin 1995). Of females that attempt to nest, 81 to 89.5 percent (Arizona; Sydeman et al. 1988, T. E. Martin cited in Kingery and Ghalambor 2001) and 91 percent (British Columbia; Campbell et al. 1997) produce at least one young bird. No information is available on lifetime reproductive success.

Habitat quality and the presence of helpers affect reproductive success. In Arizona, pygmy nuthatches produce 5.5 young per nest in high quality habitat and 4.4 young per nest in poorer habitat (Sydeman et al. 1988). At the same site, breeding units with helpers produce 5.2 young per nest, whereas those without helpers produce 4.3 young per nest (Sydeman et al. 1988).

Annual survival and life span

The survival rate of adult pygmy nuthatches (birds >1 year old) is 65 percent (Norris 1958, Martin 1995). Survival of first-year birds is more difficult to determine due to unclear dispersal patterns of young birds, but it has ranged from 27 percent (Norris 1958) to 44 percent (Sydeman et al. 1988) in two studies. Based on ratios of subadults to adults, however, Norris (1958) argues that mortality of first-year birds and adults is similar. Based on annual mortality of adults, the average life span of the pygmy nuthatch is 1.7 years (n = 122; Norris 1958). Based on recapture of banded birds, the maximum recorded lifespan is 8.17 years (Klimkiewicz et al. 1983, Klimkiewicz 1997).

Breeding site fidelity

Pygmy nuthatches show a high degree of fidelity to their breeding sites. Males may show greater fidelity to breeding sites than females, but data are scant. Of two males observed moving nest sites, one moved to a different cavity in the same nest tree, and the other moved to a distance of only 39 m to a different nest tree (Norris 1958). Banding recoveries also suggest a high degree of fidelity, with 100 of 101 recoveries occurring in the same ten-degree survey block (Kingery and Ghalambor 2001).

Dispersal patterns and non-breeders

Few data exist on the dispersal patterns of young birds. First-year birds that do not remain on their natal territory as helpers move over four times as far from their natal sites than adults move between breeding territories (Norris 1958). First-year birds move an average of 286.5 m, but they show a wide range of movements, from 0.6 m (a bird remaining in the same snag) to 533 m (Norris 1958). Except for those remaining on their natal territory to act as helpers to their parents, all movements by first-year birds exceed 150 m (Norris 1958). Immigrating young birds from neighboring territories often replace young birds that emigrate from their natal territories (Güntert et al. 1989).

Matrix model assessment

Demographic modeling is an important tool that allows conservationists to predict if a population is likely increasing, decreasing, or remaining stable, and to identify the demographic parameters that may be most important in limiting population growth

(McDonald and Caswell 1993, Caswell 2001). We used a matrix model to estimate the population growth rate (λ) of pygmy nuthatches, and sensitivity and elasticity analyses to examine the relative importance of different demographic parameters to λ . While this approach produces valuable information on pygmy nuthatch demography, readers should interpret results with caution due to limitations of available data.

We constructed a life cycle diagram for the pygmy nuthatch consisting of two stages (juvenile and adult) and transitions between stages (**Figure 9**; McDonald and Caswell 1993, Caswell 2001). Based on this life cycle, we developed a two-stage matrix population model, illustrated as:

$$\begin{array}{cc} F_1 & F_2 \\ P_1 & P_2 \end{array}$$

In this model, F_i represents fecundity in stage i and is calculated by $F_i = (P_i)(m_i)$, where m_i is the average number of female offspring produced per female in stage i , and P_i is annual survival in stage i . Note that the model represents female-dominated demography; effects of male helping behavior are not included. We calculated adult fecundity (F_2) using $m_2 = 2.48$, based on 4.4 to 5.5 fledglings per nest (data from Arizona; Sydeman et al. 1988) and assuming a 1:1 sex ratio. Due

to a lack of age-specific data, we assumed that fecundity does not vary with age. Annual adult survival data are available only from a California population (Norris 1958). To estimate annual adult survival in Region 2, where winter conditions are much more severe than at Norris's (1958) study site, we reduced the California estimate (0.65) by 10 percent, yielding an estimated $P_2 = 0.58$. We used the first-year survival figure $P_1 = 0.44$, which is based on work in northern Arizona (Sydeman et al. 1988) where winter conditions are relatively similar to those throughout much of the ponderosa pine zone of Region 2. These data produced the following numeric values for the matrix:

$$\begin{array}{cc} 1.09 & 1.43 \\ 0.44 & 0.58 \end{array}$$

Based on these vital rates, the matrix population analysis estimated population growth rate, or major eigenvector of the model, as $\lambda = 1.66$. Thus, this analysis suggests that pygmy nuthatches exhibit intrinsic population growth in Region 2.

Sensitivity and elasticity analyses allow us to examine how variation in vital rates affects λ . Sensitivity is the effect on population growth of absolute changes in vital rates and indicates the relative importance of a given vital rate to population growth. Sensitivities

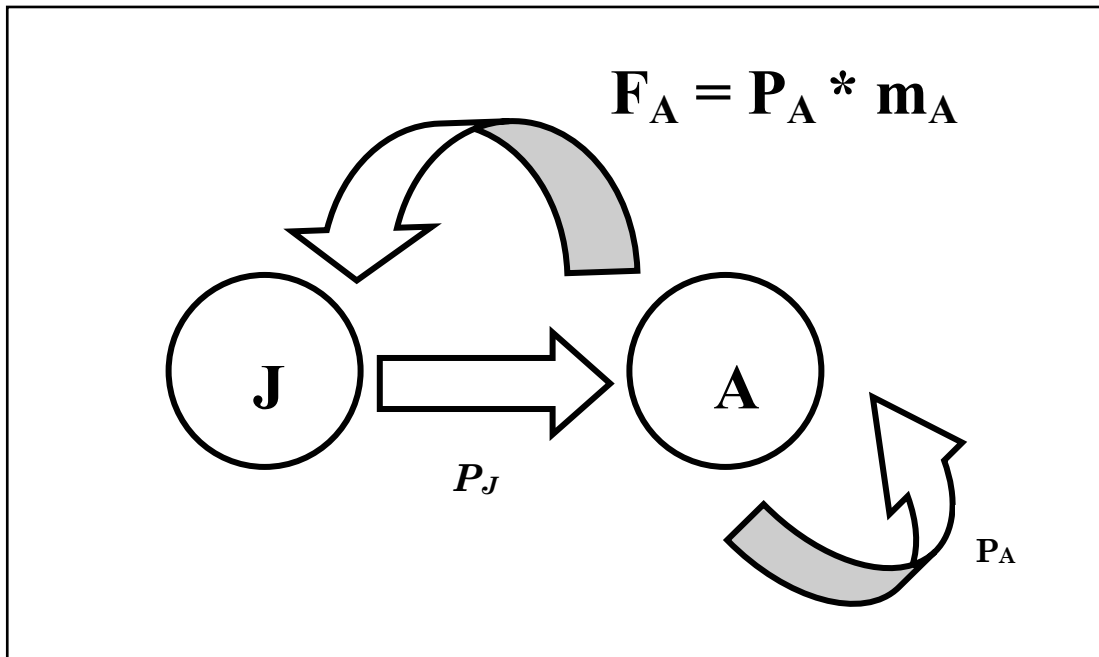


Figure 9. Life cycle diagram for the pygmy nuthatch. The life cycle contains two stages, represented by nodes (lettered circles) J and A, which represent juvenile and adult stages, respectively. Arrows represent transitions between stages, such that P_J is survival of juveniles to adulthood, P_A (a self-loop) is annual adult survival, and F is adult fertility (MA represents the average number of female offspring produced by each adult female). Juvenile fertility is zero because juvenile pygmy nuthatches do not reproduce. See text for further details.

are thus useful in evaluating the relative importance of survival and reproductive transitions, which may provide insight into the most important focus for conservation. Land managers, for example, could use sensitivity analysis to determine which stage or demographic parameter is most important to increasing the population growth of a declining species. Sensitivity analysis is also useful because it allows evaluation of effects of inaccurate estimation of vital rates from field data, or from environmental perturbations (Caswell 2001). Sensitivity analysis of the matrix model that we constructed above produced the sensitivity matrix:

0.65	0.26
0.86	0.34

This analysis suggests that λ is most sensitive to first-year survival, followed by first-year fecundity. Hence, survival and fecundity during the first year are likely the most important demographic factors to population viability, if changes in vital rates are absolute as assumed by sensitivity analysis. Changes in vital rates, however, may not be absolute because different types of vital rates (i.e., survivorship and fecundity) are measured in different units, which are not necessarily comparable on the same scale.

Elasticity analysis avoids the problem of scale inherent to sensitivity analysis (see above) by examining the “sensitivity” (i.e., elasticity) of λ to proportional changes, rather than absolute changes, in vital rates. Because they reflect proportional changes, elasticities sum to 1.0. Like sensitivity analysis, elasticity analysis is useful because it allows managers to evaluate the relative importance of different stages and demographic parameters in determining the most important focus of conservation efforts. Elasticity analysis of the matrix model that we constructed above produced the elasticity matrix:

0.42	0.23
0.23	0.12

The analysis suggests that λ is most elastic to changes in first-year fecundity, which accounted for 42 percent of the total elasticity. Next most elastic were first-year survival and adult fecundity, each of which accounted for 23 percent of total elasticity. These results suggest that variation in first-year fecundity would likely have stronger effects on λ than other demographic parameters.

Community ecology

Predators

Predators of adult and juvenile pygmy nuthatches include sharp-shinned (*Accipiter striatus*) and Cooper’s (*A. cooperii*) hawks, northern pygmy-owl (*Glaucidium gnoma*), western scrub-jay (*Aphelocoma californica*), and Steller’s jay (*Cyanocitta stelleri*) (see Kingery and Ghalambor 2001). While inside cavities, pygmy nuthatches are also vulnerable to predation by chipmunks (*Eutamias* spp.), red squirrels (*Tamiasciurus hudsonicus*), and gopher snakes (*Pituophis melanoleucus*) (see Kingery and Ghalambor 2001). Egg and nestling predators include hairy woodpecker (*Picoides villosus*), Steller’s jay, house wren (*Troglodytes aedon*), gray-necked chipmunk (*Eutamias cinereicollis*), red squirrel, and gopher snake (see Kingery and Ghalambor 2001). Pygmy nuthatches often vigorously and repeatedly attack house wrens approaching their nest tree (Kingery and Ghalambor 2001).

In response to an avian predator (e.g., *Accipiter* hawk), a pygmy nuthatch will quickly shift to the opposite side of the tree that it is on, position a limb between itself and the hawk, and flatten itself against the trunk (Denson 1981). Other observers also note that pygmy nuthatches typically freeze as a fundamental response to most predators (W.J. Sydeman personal communication 2005). Pygmy nuthatches, however, will also respond aggressively to predators in some situations. During an attack by a sharp-shinned hawk, for example, a flock of pygmy nuthatches scattered and then called constantly until the hawk left the area (Kingery and Ghalambor 2001). Two pygmy nuthatches ascended to the level of a Cooper’s hawk, which was perched in the top of a tree containing a roost cavity, and mobbed the hawk until it left the tree (Denson 1981). In addition to predators of nests and adults mentioned above, pygmy nuthatches will also mob American kestrels (*Falco sparverius*), Clark’s nutcrackers (*Nucifraga columbiana*), and Abert’s squirrels (*Sciurus aberti*) (Norris 1958, Denson 1981, Kingery and Ghalambor 2001).

Pygmy nuthatches respond to red squirrels climbing a nest tree by perching at the cavity entrance and performing an anti-predator display (similar to that

of white-breasted and red-breasted (*Sitta canadensis*) nuthatches) that can be very effective at deterring squirrels (Ghalambor and Martin 2001). During the display, the female faces downward toward the predator and spreads her wings, holds her body in a fixed position, and then sways slowly from side to side in a rhythmic movement. The squirrel typically responds by becoming motionless and fixated on the female nuthatch for up to 10 seconds, and then retreating (Kingery and Ghalambor 2001). In response to a red squirrel model placed near the nest during incubation, males reduce the rate at which they feed incubating females and increase the time they spend being vigilant (Ghalambor 1998, Ghalambor and Martin 2001). Compared to red-breasted and white-breasted nuthatches, however, pygmy nuthatches exhibit the smallest reduction in incubation feeding in response to the squirrel model, presumably because they have safer nest sites and lower vulnerability to nest predation (Ghalambor and Martin 2001).

No information exists on how habitat structure and habitat alterations affect relationships between the pygmy nuthatch and its predators. Nevertheless, because squirrels and chipmunks are the most common nest predators (Ghalambor and Martin 2001), any habitat changes that produce greater numbers of these mammals could negatively affect pygmy nuthatch breeding productivity. Similarly, any changes in habitat that allow *Accipiter* hawks to increase could increase predation on, and thus reduce survival of, adult pygmy nuthatches. Management plans designed for other species (e.g., *Accipiter* hawks) could thus have indirect consequences for pygmy nuthatches.

Competitors

Male pygmy nuthatches are behaviorally dominant over females during roosting. Within a cavity, dominant males occupy locations at the bottom of the roosting group where they derive the highest thermal benefits, while females are forced to roost near the top of the group where they receive only one-fifth of the thermal benefit of communal roosting (Hay 1983). Males may incur a cost, however, because birds at the bottom of the roosting group may occasionally suffocate (Knorr 1957).

Given that pygmy nuthatches are generally resident on their territories year-round under normal conditions, it is not surprising that territorial conflicts and trespassing are rare and, hence, that intraspecific competition for territories appears to be low. Competition among neighboring family groups for

roost cavities may be important during winter (Sydeman and Güntert 1983). At the community level, pygmy nuthatches may face strong interspecific competition for nest sites from other cavity-nesting species. Near nest sites, for example, pygmy nuthatches interact agonistically with hairy woodpeckers, violet-green swallows (*Tachycineta thalassina*), white-breasted nuthatches, house wrens, western (*Sialia mexicana*) and mountain bluebirds (*S. currucoides*) (Kingery and Ghalambor 2001), and Williamson's sapsuckers (*Sphyrapicus thyroideus*) (Dobbs et al. 1997). House wrens evict pygmy nuthatches from nest and roost cavities (Jones 1930). During the non-breeding season, pygmy nuthatches frequently occur in mixed-species flocks with mountain chickadees, white-breasted and red-breasted nuthatches, and brown creepers (*Certhia americana*) (Norris 1958, Storer 1977, Denson 1981, Kingery and Ghalambor 2001). Many of these species overlap with pygmy nuthatches in diet and foraging substrate, and thus they may compete with pygmy nuthatches for food resources. Available evidence suggests, however, that pygmy nuthatches and mountain chickadees partition food resources, to some degree, by using different foraging methods (Manolis 1977).

Ways in which competitive dynamics may change (e.g., due to increased intra- or interspecific competition for cavities) as a result of habitat alteration remain little studied. Nevertheless, maintaining suitable snag availability, and therefore nest and roost site availability, should reduce competition among secondary cavity users, and thereby allow pygmy nuthatches to maximize reproductive success (**Figure 10**).

Parasites and disease

One of eight pygmy nuthatches in Marin County, California had a "fair infestation" of *Haemoproteus* spp. (Norris 1958), and one of six in Colorado was infected by *Trypanosoma avium*, a blood marrow parasite, which was acquired from a hippoboscid (*Ornithomyia* sp.) fly (Stabler et al. 1966). Of nine pygmy nuthatches collected at Eagle Lake, California, three had blood parasites (*Trypanosoma*, *Haemoproteus*, and *Microfilaria* spp.) (Miller et al. 1978). Three of 150 pygmy nuthatches showed infection caused by an intestinal fluke (*Gyrabascus echinus* or related species), and tapeworms have been found in the intestines of several birds (Norris 1958). Pygmy nuthatches are parasitized by tick-like mites, feather mites (Acarina), and at least two species of bird lice (*Myrsidea* and *Brüelia* spp.) (Norris 1958). Pygmy nuthatch nestlings are probably infected, at least occasionally, by *Protocalliphora* blowfly larvae (see Kingery and Ghalambor 2001).

WEB				CENTRUM
4	3	2	1	

RESOURCES

water — mature forest — large, live pine trees — pine bark, needle clusters — food: insects and insect larvae

water — mature forest — large, live pine trees — pine cones — food: pine seeds

mature forest — large trees and insects — primary cavity-nesting birds — snags with cavities — roost sites

MALENTITIES

water — mature forest — large trees, snags, and insect food — primary cavity nesters — secondary cavity nesters (as competitors for nest and roost sites)

water — mature forest — large trees, snags, and insect food — primary cavity nesters (as competitors for nest sites)

water — mature forest — live trees — insects, insect larvae, and pine seeds — bark, needle cluster, and cone foraging birds (as competitors for food)

PREDATORS

alternative prey — small raptors, jays (as predators of adults)

alternative prey — House Wren, red squirrel, chipmunks (as predators of eggs and nestlings)

MATES

mature forest — snags and insect food — primary cavity nesters — snags with cavities — nest trees

water — mature forest — snags suitable for excavation — nest trees

water — mature forest — snag availability and suitable foraging habitat — nesting habitat

Figure 10. Envirogram outlining ecological relationships of the pygmy nuthatch.

No information is available on effects of parasites or diseases, but deformities are observed occasionally, such as one bird with an upper mandible twice the normal length and curved downward slightly (Kingery and Ghalambor 2001).

CONSERVATION

Threats

Management activities

Timber harvest

Effects on habitat quality and availability:

Timber harvesting may have both positive and negative influences on pygmy nuthatch habitat quality and availability, depending on harvesting strategy (e.g. clear-cut, partial-cut, strip-cut) and effects on forest structure. Timber harvesting has the potential to have direct and indirect negative influences on pygmy nuthatch habitat quality through the removal of trees used for nesting, roosting, and foraging, and on habitat availability through fragmentation of continuous forest habitat (see Road building and habitat fragmentation section below). Positive direct and indirect influences of timber harvest on habitat quality may occur through the augmenting of trees used for nesting, roosting, and foraging. For example, forest thinning may reduce competition between trees and, in time, result in the production of larger trees that are more suitable for nesting, roosting, and foraging.

Fuelwood harvesting may affect pygmy nuthatch habitat differently and occurs at two levels. At a large scale, forest managers often harvest dead or diseased trees from large areas, particularly after fires, windstorms, and other natural disturbance events. The justification for removing dead and diseased trees is to reduce the accumulation of fuelwood that could lead to high-intensity fires (see below). At a smaller scale, standing dead trees, fallen trees, and other downed woody debris are collected for firewood at campsites or other personal uses. Any fuelwood harvesting that removes standing snags is expected to negatively influence habitat quality and availability through the loss of nesting and roosting habitat. The harvesting of fallen trees and downed woody debris is not expected to have any negative consequences.

Effects on populations and individuals:

Research suggests that various timber harvesting treatments have negative impacts on pygmy nuthatches (Hejl et al. 1995, Finch et al. 1997). Comparisons

between uncut mature forests and forests that have been subject to various silvicultural treatments reveal that the density of pygmy nuthatches is significantly reduced on harvested forests (Franzreb and Ohmart 1978, Brawn 1988, Sydeman et al. 1988), and these reduced numbers are significantly correlated with the reduced volume of ponderosa pine foliage (see also O'Brien 1990). For example, Szaro and Balda (1979) report that the average number of breeding pygmy nuthatches over a three-year period was 14 pairs per 40 ha in uncut mature forests (582.5 ponderosa pines per ha), but only 4.0 pairs per 40 ha in a strip cut forest (145 ponderosa pines per ha), 1.3 pairs per 40 ha in a severely thinned forest (59.7 ponderosa pines per ha), and 13.5 pairs per 40 ha in a selectively cut forest (216.1 ponderosa pines per ha, with only some mature trees removed); pygmy nuthatches were always absent from clear-cut forests (Szaro and Balda 1979). Similarly, Balda (1975) reports the number of breeding pairs on three uncut mature ponderosa pine forests to be 26, 15, and 43 pairs per 40 ha, whereas on two plots where all snags were removed the number of pairs dropped to two and three pairs per 40 ha.

Scott (1979) reports that pygmy nuthatches density dropped from 16.3 to 7.6 pairs per 40 ha where timber harvesting reduced the basal area of live trees from 110 to 64 ft² per acre and removed all snags. In contrast, on plots where timber harvesting reduced the basal area from 107 to 51 ft² per acre but did not remove snags, the number of breeding pairs increased from 18.7 to 22.6 pairs per 40 ha (Scott 1979). During that same period, pygmy nuthatch populations on control plots, which had a standing basal area of 102 ft² per acre and were not cut, increased from 13.6 to 20.4 pairs per 40 ha (Scott 1979).

The pygmy nuthatch was one of four species that showed a significant reduction in population density with a reduction in snags (Scott 1979). These results appear to illustrate the importance of retaining snags during timber harvests. In addition, work by Balda (1969, 1975), Szaro and Balda (1986), O'Brien (1990), and Rosenstock (1996) all conclude that pygmy nuthatches prefer to forage in dense foliage and that populations decline in forests that have low canopy density, high canopy patchiness, and reduced vertical density, which are a common result of timber harvesting activities. For example, even using "coarse" forest survey plot data, O'Brien (1990) found that the number of pygmy nuthatches was significantly correlated with both foliage volume of ponderosa pine and the estimated availability of food in ponderosa pines (computed using average canopy height and canopy closure; see O'Brien 1990

for details). Furthermore, O'Brien (1990) found that the average number of pygmy nuthatches observed was much higher (6.5 vs. 1.5) and more birds were observed at more locations in a more remote, less intensively managed forest than in forest intensively managed for timber. Using a somewhat similar approach, Rosenstock (1996) found a general positive correlation between pygmy nuthatches and the diameter of pine trees.

Fire suppression and prescribed fire

Effects on habitat quality and availability:

A policy of fire exclusion during the past century has characterized forest management throughout the range of the pygmy nuthatch, and this has probably impacted pygmy nuthatch populations most significantly by changing the structure of ponderosa pine forests. Fire suppression has caused fire frequency to decline and stand density to increase dramatically in montane and upper montane forests of the Colorado Front Range (Veblen and Lorenz 1991, Veblen et al. 2000, Veblen and Donnegan 2004) and elsewhere in Region 2. A reduction in fine fuels due to heavy livestock grazing has exacerbated shifts in fire regimes and forest structure (Veblen 2000, Veblen and Donnegan 2004). Along the Colorado Front Range, and probably in Region 2 in general, historic fire regimes differed with elevation, slope aspect, and forest type. In the relatively xeric lower-montane ponderosa pine woodland, frequent fires of low severity maintained open and patchy ponderosa pine woodlands (Veblen et al. 2000, Veblen and Donnegan 2004), similar to ponderosa pine-fire dynamics in the southwestern United States (Moir et al. 1997, Bock and Block 2005). Fire suppression, which in Region 2 has been most intense in this lower montane zone, has shifted the structure of this habitat from open, patchy woodland to dense stands of young ponderosa pine trees. At higher elevations, ponderosa pine forest is more mesic, includes Douglas-fir, and grades into mixed-conifer forest. Here, forest structure was historically shaped by more infrequent, severe stand-replacing fires, which created habitat mosaics of variable seral stages on a landscape scale (Veblen et al. 2000, Veblen and Donnegan 2004). Fire suppression in lower-montane ponderosa pine forests has thus decreased pygmy nuthatch habitat quality by converting an open-canopy forest characterized by a low density of large trees to a closed-canopy forest characterized by a high density of small trees.

Severe stand-replacing crown fires, resulting in part from the accumulation of fuels through long-term fire suppression, are expected to negatively affect pygmy nuthatch habitat by reducing or eliminating

sources of food and shelter. Because periodic surface fires did occasionally burn individual trees and small clusters of trees (see Moir et al. 1997), fire suppression has also reduced the number of snags important for pygmy nuthatch nesting and roosting cavities. Restoring natural fire regimes has been proposed as a management tool (e.g., Covington and Moore 1994, Arno et al. 1995, Fule and Covington 1995). Prescribed burning should benefit pygmy nuthatches by restoring open canopy, mature forest and creating snags.

Effects on populations and individuals: Little information is available on populations of pygmy nuthatches prior to fire suppression policies, but evidence from Arizona and New Mexico suggests that the species was abundant (Scurlock and Finch 1997). Attempts to restore ponderosa pine forests to their pre-European settlement structure and function (i.e., conditions prior to fire suppression) should positively impact pygmy nuthatch populations, but too little information currently is available.

Little information exists on the short- and long-term effects of severe wildfire on pygmy nuthatches, and no information is currently available on the response of pygmy nuthatches to prescribed fire or low-intensity wildfire (Saab et al. 2005). Large crown fires appear to affect pygmy nuthatch populations negatively by reducing sources of food and shelter (Brawn and Balda 1988b). In mixed coniferous forest in Colorado, pygmy nuthatch abundance on eight replicated burned plots was significantly lower than on eight replicated unburned plots during the 0-8 year period following wildfire (Kotliar et al. 2002). During the first breeding season following wildfire in northern Arizona ponderosa pine woodland, Dwyer and Block (2000) found that pygmy nuthatches on moderately-burned sites were significantly less abundant than on unburned sites (sampling was replicated within three different wildfire areas). Examining longer-term effects in Arizona, Lowe et al. (1978) found that pygmy nuthatches were more common in an unburned plot than on plots that had undergone stand-replacing fires at various times in the previous 20 years. However, many of these burned sites may have been salvage-logged, making it difficult to distinguish fire effects from logging effects (Finch et al. 1997). Similar problems have plagued other studies (e.g., Overturf 1979, Blake 1982, Aulenbach and O'Shea-Stone 1983) attempting to quantify the effects of fire on pygmy nuthatches and other birds within ponderosa pine forests (see Finch et al. 1997). The current level of information makes it difficult to accurately predict the effects of fire on pygmy nuthatches. However, it seems reasonable to

conclude that low-intensity ground fires would have little or no negative effects, whereas high-intensity crown fires would have significant negative short-term effects because of the reduction in foraging habitat (live trees) and nesting and roosting habitat (snags).

Livestock grazing and non-native plant invasion

Effects on habitat quality and availability: Livestock grazing can influence habitat quality negatively through direct trampling or consumption of pine seedlings. In the long term, however, grazing can reduce grass cover and plant litter, which in turn can enhance survival of pine seedlings and reduce the frequency of fires. Intensive grazing, however, interacts with fire to affect habitat quality and availability negatively. The reduction of grass cover resulting from livestock grazing, when combined with fire suppression, allows denser stands of small trees and shrubs in the understory (Saab et al. 1995), increasing the likelihood of stand-replacing fires. To date, no long term studies of this kind have been carried out.

High-intensity livestock grazing also facilitates the invasion of non-native annual grasses, which tend to be fire-adapted (Saab et al. 1995). The introduction and spread of cheatgrass (*Bromus tectorum*), in particular, threatens the structure and functioning of native habitats as a result of its life history, competitive ability, and its interaction with fire. By germinating in the autumn, initiating growth early in the spring, having a highly efficient shallow root system, and setting abundant seed annually, cheatgrass quickly colonizes and dominates plant communities. Unlike native bunchgrasses, cheatgrass forms continuous dense cover, providing high fuel loads that promote more frequent, larger, more severe, and less complex fires than are allowed by native vegetation.

No study to date has investigated how the establishment or control of non-native plants influences habitat quality in ponderosa pine forests. Some techniques (e.g., prescribed fires) employed to control non-native plants are expected to have little or no effect as long as these fires are low-intensity ground fires. To the extent that establishment of non-native plants alters the recruitment of trees used for foraging, nesting, or roosting, there could be long-term negative impacts.

Effects on populations and individuals: No study to date has considered the effects of livestock grazing on the pygmy nuthatch. In the short term, it is unlikely that grazing or the invasion of non-native grasses would have any impacts negative or positive

on the pygmy nuthatch because their foraging is largely confined to foliage in large trees. Long-term grazing and the invasion of non-native grasses in ponderosa pine forests are likely to affect pygmy nuthatch populations negatively by interacting with fire suppression.

Road building and habitat fragmentation

Management activities discussed above (e.g., timber harvest and fire suppression) and others not discussed that potentially pose threats to pygmy nuthatches (e.g., mining, and oil and gas development) are often associated with the building and maintaining of access roads. Effects of road building on habitat quality and availability may occur at multiple levels, the most direct of which is the removal of trees that may result in the loss of nesting, roosting, and foraging habitat. In addition, there may be changes in the structure, density, age, and vegetative diversity of forests adjacent to where roads are built. A second level by which roads may influence habitat quality is related to the degree to which disturbances associated with vehicle use (e.g., accidental taking of individuals, noise, exhaust) of the road reduces the suitability of a particular site for breeding, foraging, or roosting.

Further, management activities and associated road building may reduce habitat availability by fragmenting ponderosa pine woodlands and, potentially, pygmy nuthatch populations. Data with which to evaluate the threat of habitat fragmentation to pygmy nuthatch populations are currently not available. Work in Europe, however, shows that habitat fragmentation strongly affects the dispersal process in the closely-related European nuthatch (*Sitta europaea*) (Matthysen and Currie 1996). Whereas the rate of territory settlement was rapid and associated with rapid pair formation in a large forest tract, nuthatches filled vacant territories at a slower rate and experienced lower pairing success in the small forest fragments (Matthysen and Currie 1996). Similar research is badly needed for pygmy nuthatches in Region 2.

Recreation

Recreational activities may negatively affect pygmy nuthatch populations through the accidental and purposeful taking of individuals, habitat modification, changes in predation regimes, and disturbance (Knight and Cole 1995, Marzluff 1997). In a review of the effects of recreation on songbirds within ponderosa pine forests, Marzluff (1997) hypothesized that “nuthatches” would experience moderate decreases in population abundance and productivity in response to impacts associated with

established campsites. Impacts associated with camping that might negatively influence nuthatches include changes in vegetation, disturbance of breeding birds, and increases in the number of potential nest predators (Marzluff 1997). However, other recreational activities associated with resorts and recreational residences might moderately increase nuthatch population abundance and productivity (Marzluff 1997). This positive effect on nuthatch populations is likely to occur through food supplementation, such as bird feeders that are frequently visited by pygmy nuthatches.

Natural disturbances

Disease and parasites

Communal roosting is a salient feature of pygmy nuthatch behavior and ecology during the non-breeding season, and it may represent an important adaptation by which birds maximize survival during the winter period in the Intermountain West, including Region 2. The high frequency of communal roosting events during the winter and the large numbers of birds observed roosting together (e.g., Sydeman and Guntert 1983) lead to the question: how does communal roosting behavior influence disease and parasite transmission, and thus the importance of diseases and parasites as causes of mortality in pygmy nuthatch populations? Data are not currently available with which to address this question, but it is likely that diseases and parasites represent an important component of pygmy nuthatch ecology and demography.

Insect epidemics and mistletoe infestation

Within ponderosa pine forests, attention and concern over insect infestations is primarily focused on mountain pine beetles (*Dendroctonus ponderosae*) because of their potential to kill trees that would otherwise be desirable for harvesting. However, the death of individual or small patches of ponderosa pine trees resulting from bark beetle (*Dendroctonus* or *Ips* spp.) infestations may have beneficial effects on pygmy nuthatch habitat because small-scale tree mortality creates snags suitable for nesting and roosting cavities. Ponderosa pine mortality resulting from beetle and mistletoe epidemics was historically regulated by periodic fires (see Moir et al. 1997). Given current forest conditions, fire regimes, and the likelihood of severe stand-replacing wildfires, however, such epidemics may be more likely to result in large-scale tree mortality, which could have negative consequences on pygmy nuthatch foraging habitat because of the large-scale loss of foliage associated with live pine trees.

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic plants that retard growth, reduce seed production, and kill host trees, thus contributing to a mosaic forest structure through effects of variation in tree growth and mortality (Tinnin 1984). Bennetts et al. (1996) studied the effects of dwarf mistletoe infestation on the abundance and diversity of breeding bird communities in central Colorado. While the number of cavity-nesting species was positively correlated with the level of mistletoe infestation, no significant relationship existed between pygmy nuthatch abundance and mistletoe infestation (Bennetts et al. 1996).

The ultimate effects of insect and mistletoe epidemics may be related to the scale at which outbreaks occur. Small insect outbreaks that only kill small patches of trees may have beneficial effects on habitat quality, by increasing the availability of snags for nesting and roosting. However, large-scale epidemics that result in large amounts of tree mortality could have negative consequences through the large-scale loss of foliage associated with live pine trees.

Wildfire

See Fire suppression and prescribed fire section above.

Wind and weather events

Wind events have the potential to negatively influence habitat quality and availability by blowing down snags used for nesting and roosting. In addition, extreme cold temperatures and drought may alter habitat quality through their effects on tree mortality and availability of food resources. Cold temperatures, particularly during the winter months, have the potential to influence pygmy nuthatch populations negatively. Szaro and Balda (1986) report that breeding bird densities (including pygmy nuthatches) were highest following the mildest winter conditions, and bird densities were lowest following a winter with the highest winter snowfall on record in their Arizona study sites. Given that pygmy nuthatches have a low tolerance to cold temperatures, as exemplified by their use of torpor and communal roosting (e.g., Hay 1983), cold winter temperatures may have disproportionately greater effects on their populations.

Conservation Status of the Pygmy Nuthatch in Region 2

Within Region 2, the pygmy nuthatch is a rare resident in the Bighorn Mountains area of north-central

Wyoming (Downing 1990), central Wyoming south of Casper, the Snowy Range in south-central Wyoming (Luce et al. 1997), the Black Hills in northeastern Wyoming and western South Dakota (Peterson 1995, Luce et al. 1997), and the Pine Ridge and Wildcat Hills areas of northwestern Nebraska (Mollhoff 2001, Sharpe et al. 2001). In Colorado, the species is widespread and generally common in low to mid-elevation pine habitats of the Front Range, the Uncompahgre Plateau, and the San Juan Mountains. The breeding distribution of the pygmy nuthatch in the Southern Rockies coincides very closely with the distribution of ponderosa pine forest (see Habitat section above). In fact, previously unknown populations were recently discovered by surveying isolated patches of ponderosa pine in far northwestern Colorado (Moffat County) and east of the Front Range (Elbert County) (Jones 1998). The species' widespread occurrence in much of western Colorado (i.e., Grand, Eagle, Garfield, Pitkin, northeastern Mesa, eastern Montrose, Gunnison, and Delta counties), as shown by Andrews and Righter (1992), probably reflects non-breeding records, mainly in lodgepole pine forest (Kingery and Ghalambor 2001). Colorado Breeding Bird Atlas surveys covered this area well and found little evidence of breeding pygmy nuthatches or appropriate habitat (Jones 1998).

The status of pygmy nuthatch populations in Region 2 is not well known, and robust estimates of population trends are not available. Based on BBS data, populations in Region 2 (e.g., Colorado, Southern Rocky Mountain BBS region) may be declining (**Table 1**). However, these data are largely unreliable due to small sample sizes (i.e., low number of routes with pygmy nuthatches present or low abundance of pygmy nuthatches on routes) or high variability (Sauer et al. 2004). BBS data for states and areas within Region 2 contain less than 1.0 birds per route (low abundance), are based on less than 14 routes for the long term (small sample size), and/or are so imprecise that a 3 percent per year change would not be detected over the long term (Sauer et al. 2004). Conversely, CBC data appear to suggest that populations may be increasing in some areas of Region 2 (i.e., Colorado; **Table 2**), but these data also should be interpreted with extreme caution due to the non-random nature of CBC location selection and sampling techniques. Consequently, population status and trends of the pygmy nuthatch in the Southern Rockies are unclear at this time.

Some lines of evidence suggest that the species is vulnerable to demographic stochasticity, with local populations exhibiting large fluctuations in the number of individuals. The potential for local populations to

occasionally “crash,” in conjunction with their low dispersal ability, raises concern that isolated populations may be vulnerable to local extirpation.

Potential Management of the Pygmy Nuthatch in Region 2

Implications and potential conservation elements

A review of the published scientific literature reveals that pygmy nuthatches reach their highest abundance in undisturbed, mature stands of ponderosa pine. Factors affecting the abundance and viability of populations of the species, both in Region 2 and rangewide, are related primarily to the species' foraging and nesting/roosting needs. As reviewed above, populations decline in harvested forests that have low canopy density, high canopy patchiness, few numbers of large diameter trees, and reduced vertical density. These declines are attributed to the preference of pygmy nuthatches for foraging in dense pine foliage and a reliance on the cone crops for pine seeds, which make up a large portion of their diet during the non-breeding season. In addition, population declines and reduced reproductive success in harvested forests have been attributed to a reduction in the number of snags, which are required for both nesting and roosting.

An additional concern regarding the management of the pygmy nuthatch is its limited dispersal ability, which may isolate populations, thus potentially reducing the likelihood of individuals moving between populations or of recolonization of suitable, but isolated, patches of habitat. Within Region 2, the reduced dispersal ability of pygmy nuthatches is of particular concern because many ponderosa pine forests occur within mountain ranges that are isolated from each other by grass and shrub-dominated habitats. For example, pygmy nuthatch populations in the Black Hills region of western South Dakota, western Nebraska, and far eastern Wyoming are separated by hundreds of miles from their nearest populations in the Bighorn and Laramie mountains.

Currently no management or conservation plans have been developed specifically for the pygmy nuthatch. However, current snag-retention standards for Region 2 forests and snag-retention objectives for management areas on Region 2 forests that target cavity-nesting bird species in ponderosa pine forest may benefit the pygmy nuthatch under some circumstances. Because snag availability is influenced by a number of human activities and natural events, management

strategies should aim to increase or maintain the number of large snags, particularly within the context of mature forests and in burned areas.

Conservation plans should also consider the connectivity of patches of ponderosa pine habitat and the role of fire suppression policy. Attempts to maintain habitat connectivity between patches of ponderosa pine may facilitate movement of pygmy nuthatches over a larger area. In practice, this may translate into the configuration of timber harvest layouts. However, the spatial scale at which such practices should be carried out remains unknown because few studies have examined the distances individual birds move within a matrix of suitable and unsuitable habitat. Finally, because pygmy nuthatches rely so heavily on snags for breeding and roosting, fire suppression policy should be flexible enough to allow for some fires to burn and to allow for natural successional patterns while at the same time protecting snags and foliage. In practice, such a policy could result in a mosaic of forest conditions (i.e., burned vs. unburned; mature vs. young) that are thought to mimic natural heterogeneity.

Tools and practices

Inventory and monitoring

Species inventory: There are three general methods for conducting bird surveys and inventories to determine the presence or absence of a given species (see Ralph et al. 1995, Nichols and Conroy 1996): 1) area-specific checklists, 2) count-based indexes, and 3) point counts. These methods are discussed in more detail below.

Area-specific checklists provide presence/absence data by having multiple observers visit the same area and generate replicate checklists of all species observed (Nichols and Conroy 1996). This method allows users to estimate such variables as the presence or absence of a particular species and species richness for the area as a whole. The strength of this approach is that it is relatively simple and with a minimum of five replicate checklists, statistical estimation procedures can be applied to each site (Nichols and Conroy 1996). The weakness of this approach is that no estimates of population size can be obtained, and because all species have a nonzero probability of being encountered, some statistical biases exist (Nichols and Conroy 1996). This approach is relatively cost-effective, requiring a minimum of five checklist participants that are of similar ability and that can visit the same site on a single or multiple occasions.

Such an approach can be used to obtain data for a large number of areas over a relatively short time.

A second approach to sample bird populations is count-based population indexes. Most bird surveys are count-based indexes, in that they provide an index to population numbers, based on numbers counted rather than actual population sizes. This method is widely used in regional surveys, such as BBS and CBC. The method can be useful for detecting population trends over large areas, but these surveys all share the same weakness of collecting general information without completely standardized protocols, and this introduces variation that complicates the interpretation of the data (see Barker and Sauer 1995, Sauer et al 1995). Depending on the geographic and temporal scales to be covered, such an approach can range from being very cost-effective to fairly expensive.

The third and most commonly used approach is point count surveying, in which an observer stands at a predefined location and counts birds with a specific protocol (Ralph et al. 1995). This is the standard approach for most monitoring programs, including those used by the USFS and its collaborators. Point counts can be used to appropriately estimate species richness for each point and for groups of points, but estimates of relative abundance are somewhat limited in their applicability (Ralph et al. 1995). If the goal of the point count is to obtain information on a single species or a group of species, the specific methodology chosen can be modified to increase the probability of detection. Standardized methods and observer training are essential to ensuring some level of comparability of results, but differences among observers in ability will always make such comparisons problematic. However, this approach is still the most reasonable means of indexing change over time and, in combination with additional vegetation data, is the basis for building a better habitat capability model (HABCAP) for the pygmy nuthatch. It is also possible to estimate distances to each individual bird that is detected, allowing for estimation of total densities (Bibby et al. 1992). As with non-standardized counts, the cost and time requirements will depend on the geographic and temporal scales to be covered. Additional time and cost may arise depending on the specific protocol used.

Population monitoring: There are three general approaches to monitoring bird populations: constant-effort mist-netting, nest searching, and different modified census methods (Ralph et al. 1993). As with any monitoring plan, the choice of methodology will

depend on the specific objectives. Ralph et al. (1993) suggest that prior to implementing a monitoring program the following steps should be taken:

- (1) decide the objectives and goals desired
- (2) determine whether monitoring is the way to accomplish these
- (3) with the goals firmly in mind, write down the questions being asked, clearly and objectively
- (4) determine which monitoring methods most directly answer the questions posed
- (5) review the types of data that can be obtained from these methods and outline exactly how these data will answer the questions
- (6) outline the analytical methods that can be employed
- (7) determine the cost, logistics, availability of personnel, and probable length of commitment to the project
- (8) write a study plan and have it reviewed by a person competent in research and statistics.

This final procedure is vital because accumulation of a database does not itself lead to meaningful analyses later (Ralph et al. 1993). Below is a brief description of different approaches to population monitoring and some of their strengths and weaknesses.

Constant-effort mist-netting is a methodology where birds are captured and banded using mist nets that are located throughout a given habitat (Ralph et al. 1993). The most common protocol for constant-effort mist-netting is the one used by the Institute for Bird Populations called Monitoring Avian Productivity and Survivorship (MAPS). This is a national program with numerous collaborators, including the USFS. The advantages of this method are that by handling and banding individual birds, information about the various attributes of the population can be gained (e.g., age and sex ratios, physiological condition) (Ralph et al. 1993). Although some studies have used mist-netting to assay population size, for most species, censuses are the best method for this (see below) since netting provides relatively fewer data points per unit time (Ralph et al. 1993). The disadvantage of constant-effort mist-netting is that biases can exist in the probability of capture for

some species and in some habitats, and reproductive parameters like fecundity are not collected. Depending on the size of the area to sampled, it is recommended that four to six people operate 20 to 30 different mist-net stations. The cost of such an approach will vary on the experience level of those employed and the duration of the sampling period, which is usually two to four months depending on the length of the breeding season.

A second approach to monitoring relies on nest searching. Nest searches provide the most direct measurement of nest success in specific habitats and allow for identification of important habitat features associated with successful nests, insight into detailed habitat requirements and species coexistence (Ralph et al. 1993). Nest searches have an advantage over constant-effort mist-netting, in that the measures of reproductive success are direct and habitat-specific. However, they are more limited as to the area surveyed and do not measure individual survivorship. This method samples birds from a larger area, and the data derived may therefore have wider applicability, but are not habitat-specific (Ralph et al. 1993). The most common standardized protocol in nest search studies are those set forth by the Breeding Biology Research and Monitoring Program (BBIRD), which is a national cooperative program that allows participants (including the USFS) to share and compare data and allows examination of large-scale patterns and trends in breeding bird populations. Depending on the number of species being monitored and the size of the habitat being searched for nests, between four and eight people usually search for nests on sites they visit on alternating days. Again, the cost of such an effort will depend on the experience level of the nest searchers and the length of the breeding season.

A final approach for monitoring populations relies on census methods. There are four general census methods: point counts, spot-mapping, strip counts and area searches.

Point counts are the best approach for most surveys and have been adopted as the standard method for monitoring most bird populations (Ralph et al. 1993, 1995). The two most suggested types of point counts are extensive point counts, which are intended to sample a series of points over a large region, and intensive point counts, which are placed within a local area like a mist-net plot or nest search plot. The specific goals and objectives of the monitoring scheme will determine which approach is most appropriate. The benefits of standardized point counts are that a much larger area can typically be covered than when using

constant-effort mist-netting and nest searches, and that actual estimates of population size can be determined. The drawbacks of these approaches are that they do not provide any data on the reproductive success of a species or any of the individual level parameters such as age and sex ratios. In both point count methods, observers with good identification skills are needed for a minimum of three to four hours a day, depending on the distance between sampling points (Ralph et al. 1993). These considerations will also determine the cost of implementing such a plan.

Strip counts or strip transects are similar to point counts, but the observer records all birds seen or heard while traversing a trail or pre-defined area (Ralph et al 1993). This method is primarily used in very open terrain and not recommended for forested areas (Ralph et al. 1993). Area searches are described above under inventory approaches. This method can be a particularly cost-effective way of counting birds when a large number of people are involved. For example, if a large number (>20) of volunteers are available, then each person can survey all the birds in a given area decided upon.

Habitat inventory and monitoring: There are no existing protocols for carrying out habitat monitoring specifically for the pygmy nuthatch. However, given what is known about the biology of the pygmy nuthatch, any habitat monitoring should ideally inventory and track the following attributes within Region 2:

- ❖ distribution of mature ponderosa pine forest stand data
- ❖ density of trees from different size and age classes
- ❖ spatial distribution of ponderosa pine forest patches
- ❖ distance between forest patches to the nearest mature stands
- ❖ percent canopy cover
- ❖ abundance and density of large snags
- ❖ age, hardness, and condition of these snags
- ❖ spatial distribution and history of fires within these forests

- ❖ spatial distribution and history of insect outbreaks
- ❖ spatial and temporal variation in cone crop production.

The collection of these data could then be used to generate layers in a GIS database that would allow for detailed tracking of the habitat. In conjunction with population monitoring (see above), such habitat monitoring would provide valuable information on the habitat conditions within Region 2 that support the highest numbers of pygmy nuthatches.

Management tools and approaches

No specific management practices have been implemented to target pygmy nuthatches throughout their range, but national forests generally conform to a common management practice of retaining snags in harvested areas, a practice that can benefit pygmy nuthatches. Typically, Region 2 national forests (e.g., Black Hills, Rio Grande, White River) seek to retain three snags (>9-10 inches dbh and >25 feet tall) per acre (7.5 snags per ha) in ponderosa pine habitat, with at least one snag, or 25 percent of retained snags (if more than three snags are retained) being >14-20 inches dbh, in management (e.g., timber harvesting) or “project” areas (K. Burns personal communication 2006, K. Giezantanner personal communication 2006, L.K. Wiley personal communication 2006). These Region 2 snag-retention goals are consistent with previous suggestions for the minimum number of snags per hectare for cavity-nesters such as the pygmy nuthatch. In addition, it has been proposed that snags should be of relatively large diameter (48.3 cm dbh; Clark et al. 1989) and relatively soft to accommodate the weak excavating abilities of species like the pygmy nuthatch (DeGraaf et al. 1991, Raphael 1980). Various methods have been suggested for creating snags, including girdling of trees, burning individual trees, injecting heart rot fungus into live trees, prescribed burning, topping trees, and erecting nest boxes.

Still, no study to date has evaluated the degree to which such management practices are effective for pygmy nuthatch conservation. Current information on the implementation success of snag retention policies in Region 2 is not available. Ffolliott (1983) found that the suggested USFS policies for snag retention were not being met in Arizona, nor is there more current information on whether practices on Arizona

forests have changed since that report. Programs and studies that monitor snag density and other important aspects of pygmy nuthatch habitat should therefore be encouraged.

As part of Wyoming's PIF conservation plan, Nicholoff (2003) suggests a series of potential elements to include in future management efforts:

❖ **Habitat objectives**

- ❖ maintain open stands of mature to old growth ponderosa pine
- ❖ maintain a mosaic of large trees and snags, in clusters, with an open canopy in areas where pygmy nuthatches occur

❖ **Management recommendations**

- ❖ implement woodland management practices that maintain open stands of mature to old growth ponderosa pines
- ❖ retain snags and all trees with nest cavities, preferably in clusters; a minimum of three to five large (>48 cm dbh) snags per acre (7 to 12 per ha) should be left standing
- ❖ retain mature and decadent trees for future snag production, particularly where existing snags are uncommon
- ❖ use prescribed fire to maintain open stands of forest and woodland where pygmy nuthatches occur
- ❖ establish and maintain a nest box program where snags are unavailable and the lack of nest sites is limiting pygmy nuthatch reproduction; nest boxes should be monitored regularly throughout the nesting season to evict unwanted species (e.g., rodents, insects) and to clean out "dummy" nests built by house wrens
- ❖ avoid or minimize insecticide use until pygmy nuthatches and other insectivores have completed their breeding cycle; where possible, allow insect outbreaks to proceed naturally.

Information Needs

In comparison to many of North America's songbirds, much information is known about the biology of the pygmy nuthatch. However, most of this information is based on populations from Arizona and California, and much more information is needed on the status of populations, reproductive success and annual survival, and local movements throughout Region 2. Information needs to develop

a scientifically sound conservation strategy for the pygmy nuthatch throughout Region 2 are discussed in order of priority below.

Estimates of local abundance and distribution

The first and most important step in establishing a conservation strategy would be to conduct a Region 2-wide survey to determine the distribution and abundance of pygmy nuthatch populations. A modified point-count method is suggested as the most effective method to census specifically for pygmy nuthatches (or for a group of species that includes the pygmy nuthatch). The sampling area should cover all forest stand types that include ponderosa pine, including but not limited to a range of habitat types from mature undisturbed forest to heavily logged or disturbed sites. Each sampling unit within the entire sampling area should be a minimum of 40 ha to allow for thorough coverage and increased chance of detection. Counts should be conducted in late spring and early summer to coincide with the time of the breeding season, and additional counts can be made in early fall to obtain a non-breeding estimate. Finally, before embarking on any population monitoring/census, some attempt should be made to establish statistical power and effect size to ensure that the resulting data will provide the necessary inference.

Supplementing estimates of pygmy nuthatches with information on important habitat features, such as snag availability, would provide insight into those habitat features that distinguish between good and poor quality habitat. Additionally, these data can be incorporated into existing forest stand data in conjunction with already available HABCAP models (Mills et al. 1996) to examine habitat associations and amount of potential habitat available. Conducting these censuses is a relatively inexpensive way of assessing baseline estimates of abundance, distribution, and habitat associations. Information obtained from these censuses will allow further investigation into more detailed questions such as snag availability within different landscapes and effects of different management activities.

Habitat requirements associated with reproductive success and annual survival

Measures of population abundance alone can be misleading indicators of habitat quality and population health (Van Horne 1983). In order to accurately assess the population status of pygmy nuthatches in Region 2, information is needed on the reproductive success and annual survival of birds nesting and wintering

in different habitat types. Of the different protocols available for measuring reproductive success, it is suggested that a BBIRD-type methodology be given priority. This method combines nest searching with a vegetation sampling scheme that measures those features of the habitat that are correlated with high reproductive success and/or annual survival. Vegetation sampling should be done at different scales that encompass the nest or roost site, the territory, and the landscape matrix. Specific attention should be paid to nest and roost site characteristics such as the diameter of snags used and the availability of snags within the territory. Comparisons between used and unused snags would also be useful in determining preference. Nest success and annual survival data, in combination with vegetation data, could then be incorporated into a GIS-based program to examine the spatial distribution of reproductive success and annual survival, and associated habitat features. This approach could also be combined with management activities such as timber harvesting and prescribed fires to investigate the effects of different habitat alterations.

Local movement patterns

Existing information suggests that pygmy nuthatches have very limited movement patterns, and this lack of movement may make them vulnerable to the effects of habitat fragmentation. Information on local movement patterns can be obtained by following individual birds over the course of a year. Such an approach would provide a number of important data sets. First, either through re-sighting of banded birds or use of radio-telemetry, individuals can be followed to determine the size of territories and scale of movement on the landscape. Questions that could be addressed include whether particular habitats are avoided, are there important corridors that connect habitats, and what are the vegetation features associated with these

areas. Another approach to answering these questions could be to use genetic markers, which would provide information on gene flow and effective population size. Combining this type of genetic data with actual movement patterns of individuals would be a particularly informative project.

Response to threats

Applied research examining how pygmy nuthatches respond to management activities (e.g., controlled burning) and natural habitat disturbance (e.g., beetle infestations), at both individual and population levels, is currently unavailable and is necessary to understand the significance of potential threats. For the threats outlined previously (see Conservation section above), what level of disturbance affects population density, reproductive success, and annual survival of pygmy nuthatches? Although some data are available from Arizona, work investigating the response of pygmy nuthatches to various timber management treatments, as well as firewood collecting, is badly needed for Region 2. Despite the importance of fire in the ponderosa pine ecosystem, only work examining effects of high-intensity wildfire on pygmy nuthatch abundance has been conducted in Region 2 (Kotliar et al. 2002), and no information is available on how the species responds to low-intensity wildfire or controlled burning (Saab et al. 2005). In addition to timber and fire management work, replicated study designs investigating pygmy nuthatch response to road building, habitat fragmentation, recreational activity, and bark beetle infestation would be particularly useful. Finally, previous work has measured only density or abundance as a response variable. Where feasible, future work should incorporate demographic variables (i.e., reproductive success, annual survival) when considering pygmy nuthatch response to disturbance.

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LIST OF ERRATA

08/29/06 On March 21, 2006 the White River National Forest ammended their Forest Plan to revise their list of MIS. The pygmy nuthatch was not included on that revised list.

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